AN ABSTRACT OF THE THESIS OF

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Title: The Level of Knowledge Required in Various Manufacturing Engineering Competency Areas in the State of Oregon

Abstract Approved: Redacted for Privacy
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This study was conducted to determine the level of knowledge required by graduating manufacturing engineering students in various manufacturing engineering competency areas as perceived by managers of manufacturing from 17 major manufacturing industrial classifications in the state of Oregon.

Methods and Procedures

A preliminary listing of competency areas was developed by reviewing literature in manufacturing, engineering, management and education. This preliminary listing was presented to a jury of experts who validated its content and suggested revisions. The final listing was then developed into a questionnaire which was field tested with managers of manufacturing. This final questionnaire contained 56 manufacturing engineering competencies with a five-point Likert-type scale consisting of not necessary, minimal, general, substantial and advanced as response selections to determine the level of knowledge required. A

selected sample of 158 manufacturing managers responded to the questionnaire. The results were statistically analyzed with the one-way analysis of variance and the Student-Newman-Keuls test.

Findings and Conclusions

The compency area mean scores ranged from 3.8153 to 1.8089 with 21 competency areas requiring substantial knowledge, 28 requiring general knowledge, and 7 requiring a minimal knowledge level. The competency area requiring the highest level of knowledge was the area of energy conservation while the area of fine arts was perceived as requiring the lowest level of knowledge. Significant differences were found in 18 of the 59 competency areas included in the study. Of the ten significantly different competency areas which could be specifically identified, there were seven cases where the significantly different group was the Apparel and Other Finished Product classification.

Recommendations

Based on the findings of the study, it was recommended that 49 of the 56 competency areas in the study be included in the manufacturing engineering curriculum and that the remaining 7 competency areas should not be emphasized in curriculum planning.

The Level of Knowledge Required in Various Manufacturing Engineering Competency Areas in the State of Oregon

by

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M.R.N.

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I. INTRODUCTION

The Problem

The central problem of this study involved the identification and validation of selected competency areas in manufacturing engineering needed for preparing university students for employment in industry. These competencies will provide a base for developing a manufacturing engineering education program.

The problem involved the answering of the following question: What levels of knowledge of manufacturing engineering competencies do practicing managers of manufacturing find to be essential or desirable for preparing students in manufacturing engineering education in the state of Oregon?

Purpose of the Study

The purpose of this study was:

1. To determine the acceptance and the level of knowledge required in 59 manufacturing engineering competency areas through data gathered from manufacturing managers. This information will establish a base for the manufacturing engineering curriculum at Oregon State University.

1a. To determine the mean scores for acceptance of content by manufacturing engineering managers in 17 of the 19 industrial manufacturing groups listed in the Standard Industrial Classification Manual of 1972.

1b. To identify differences among the 17 major industrial classifications.

1c. To identify competencies needing additional consideration for aiding the curriculum decision making process for the manufacturing engineering program.

Need for the Study

The United States is an industrial society. Through its evolution, and particularly since World War II, the development, expansion, and complexibility of manufacturing industries is unparalleled in history. This has resulted in an ever increasing demand for engineers in manufacturing. The education of manufacturing engineers, therefore, takes on an important and much needed role in meeting society's industrial/manufacturing needs.

Due to manufacturing engineering's dynamic nature (Little, 1970), manufacturing engineering education must also change and adjust so that it provides current, relevant information which best represents the technology of manufacturing. To do this, it is imperative that the curriculum be reviewed and evaluated periodically so that it may be developed and revised to present current, appropriate information and solutions to today's manufacturing problems (Glick, 1975; Olson, 1975).

At the present time, there are no available curriculum guidelines for manufacturing engineering in the state of Oregon. Studies by the Society of Manufacturing Engineers (SME), (1970), provided curriculum guidelines to be used by the Engineering Council for Professional Development (ECPD) for accreditation purposes. While providing an informative curriculum framework at the national level, it <u>did</u> <u>not</u>:

1. Identify manufacturing engineering competency needs as identified by regions or states,
2. Provide a guideline which identifies manufacturing engineering competency needs for the 1980's because the research was compiled in 1968.

Studies at a state level such as the Arizona study (Lee, 1968) dealt with all engineering disciplines. While this study serves as support for the need of the type of information this researcher is trying to provide, it does not provide specific information about the requirements of Oregon's industries in the area of manufacturing engineering.

A study by Moon (1968) dealt with manufacturing in the state of Oregon. The focus of the research, however, was concerned with the identification of industrial process operations with the direction toward planning industrial arts laboratories. The following events which have developed serve as evidence of the need for manufacturing engineering education in the state of Oregon.

1. The assembly of a manufacturing engineering advisory board whose function is to guide the development of a manufacturing engineering program in the state of Oregon at Oregon State University (1978 to present).
2. A grant from the National Science Foundation to assist in the development of the manufacturing engineering program at Oregon State University (1979).
3. The adoption of a manufacturing engineering program at Oregon State University by the Oregon Board of Higher Education (1979).
4. The funding of this new program by those industries on the Advisory Board to insure the program's success (1980).

Assumptions

The conclusions of this study are based on the assumptions that:

1. The sampling was confined to those persons who were in charge of manufacturing management at representative companies in the state of Oregon.
2. The sample of respondents adequately and accurately represented the manufacturing population of Oregon.
3. The respondents were competent in recognizing and

discussing various manufacturing engineering competencies required in their particular industry.

4. The questionnaire obtained responses which were valid and reliable.
5. The manufacturing managers who responded were no different than those who did not respond.

Procedure of the Study

The steps taken to solve the problem were:

1. The development of a survey instrument to determine the acceptance of content for use in curriculum development.
   A. The development of a preliminary listing of manufacturing engineering competency areas which served as a basis for the development of the final listing of manufacturing engineering competencies.
   B. Using the preliminary listing of competencies, a jury of experts, composed of the Manufacturing Engineering Advisory Committee, revised the final listing of manufacturing engineering competencies.
   C. From this list, a questionnaire was developed.

D. This questionnaire was presented to the Manufacturing Engineering Advisory Committee for evaluation of content, coverage, clarity, and format.

E. A pilot study was conducted to test the instrument.

F. The final instrument was revised based on the results of the pilot study.

2. The assignment of a score to the questionnaire utilizing a sample of manufacturing engineering managers.

A. The selection of manufacturing firms from the Directory of Oregon Manufacturers 1979-80 which represent 17 of the 19 industrial manufacturing groups listed in the Standard Industrial Classification Manual of 1972.

B. The assignment of a score to the questionnaire by one manufacturing manager from each of the firms selected.

3. The statistical analysis of the data.

A. Determine a mean score comparison and ranking of the 56 competencies among the 17 major industrial classifications.

B. Determine if a significant difference existed between the various industrial manufacturing groups' mean scores of acceptance of competencies using the one-way analysis of variance F-statistic.

Definition of Terms

The following definitions are provided for clarification. It is assumed that all other terms used in this study are self-defining.

Competency Area. A category of desired student performance representing demonstrable ability to apply knowledge, understanding, and/or skills assumed to contribute to success in life-role functions (Stamps, 1979, p. 18).

Manufacturing Community. Members of that fraction of industry who make or process products, especially on a large scale and with machinery.

Manufacturing Engineer. That person who plans and selects methods of manufacture, designs equipment for manufacturing, researches and develops new manufacturing techniques and improves those techniques which already exist.

Manufacturing Engineering. The planning and selection of the methods of manufacture, the design of equipment for manufacturing, and research and development tending to improve efficiency of established manufacturing techniques and to find new ones (Little, 1968, p. 3).

Manufacturing Manager. A person who plans, organizes, and controls the manufacturing personnel and procedures, with the assumption that this person also has knowledge of the requirements for working in the field of manufacturing engineering.

Technology. Accumulative knowledge, techniques and skill, and their application in creating useful goods and services. (Dewhurst, 1955, p. 834).

II. REVIEW OF THE RELATED LITERATURE

The selected literature is presented in three sections. The first section identifies the role of a manufacturing engineer. The second section reviews studies related to identifying educational needs of manufacturing engineers. The third section provides support for the evaluation of competencies and the methodology utilized in this study. These studies are presented in chronological order.

Literature in curriculum decision-making, planning and development as well as historical background in manufacturing engineering education will not be discussed as it is felt that the selected literature provides adequate support for this study and that extensive coverage of those areas can be found in Stamps (1969) and Battelle (1979), respectively.

The Manufacturing Engineer

A frequent dilemma in evaluating characteristics of manufacturing engineering is to distinguish the differences between manufacturing engineering and other industrial oriented engineering disciplines. Industrial and mechanical engineering both have very closely related functions to manufacturing engineering. The mechanical engineers are trained to choose materials and to design power and mechanical parts, fastening devices and other machine elements. The industrial engineer designs, improves and installs systems of people, materials and equipment so that they all work together. Often, the mechanical engineer or industrial engineer also performs a manufacturing engineering function, mainly the improvement of a product design from a manufacturing standpoint (producibility), planning methods of manufacturing and the development of tools and machines so that they work smoothly together. This inter-relationship or overlap has caused some concern in the field as illustrated by the following anonymous quote:

> The definition of a manufacturing engineer should be clearly, and definitely understood. Since the industrial engineer is often very close in function, the differences, if any, should be expounded upon; otherwise one or the other definition should be dropped (Battelle, 1979, p. B-33).

The responsibilities of manufacturing engineers typically involve:

> ....developing methods of manufacture, and designing tools and equipment for manufacturing, in addition to administrative and supervisory responsibilities. The groups within their company with whom manufacturing engineers most frequently interact include shop operations, product engineering, tooling, and higher management. Outside their company, the people they most frequently contact are vendors and customers. (Battelle 1979, p. 3).

In a more general sense, a manufacturing engineer is responsible for designing a system of processes, materials and personnel in an effort to produce the best product at the lowest possible price:(1)

- A Production Economist
- A Systems Manager
- A Manufacturing Planner
- A Resource Conservationist

(1) Adapted from bulletin by M.R. Nichols, Department of Industrial Engineering, Oregon State University, 1980

- A "Shirt Sleeve" Engineer works within management <u>and</u> Production

Perhaps one of the better definitions of manufacturing engineering is that which was adopted by the Society of Manufacturing Engineers Board of Directors on May 8, 1978 :

> That specialty of professional engineering which requires such education and experience as is necessary to understand, apply, and control engineering procedures in manufacturing processes and methods of production of industrial commodities and products; and requires the ability to plan the practices of manufacturing, to research and develop the tools, processes, machines, and equipment, and to integrate the facilities and systems for producing quality products with optimal expenditure. (Battelle, 1979, p. 9)

Related Manufacturing Engineering Studies

In a study sponsored by SME (Society of Manufacturing Engineers), Little (1968) undertook a survey to assess the people in the field of manufacturing engineering and the manufacturing engineering profession. Education, advancement, professional position and future trends were some of the topics brought out in the study. Discussions and 4009 questionnaire responses from manufacturing engineers (50%) and top/middle management (34%) provided the data. The respondents were well distributed over the industrial fields represented by the following Standard Industrial Classifications: (1) 3400-Fabricated Metals Products; (2) 3500-Machinery (except electrical); (3) 3600-Electrical Machinery; (4) 3700-Transportation.

This information was then tabulated and rank ordered for analysis. Some of the major conclusions from this analysis identified that those manufacturing engineers who work in smaller companies (less than 10,000 employees) find that their function is one or two levels removed from the president and that the higher the level of education one receives in manufacturing engineering the greater the chance of promotion into middle management and the greater the professional achievements as compared to a manufacturing engineer with less education. A profile of the manufacturing engineer's duties was developed by identifying the percentage of engineers surveyed who were involved in specific functions. The results were as follows: (1) Developing Manufacturing Methods (65%); (2) Sequencing of Operations (40%); (3) Detail Cost of Manufacturing (39%); (4) Supervising (38%); (5) Designing Tools and Equipment (36%); (6) Project Planning (35%); (7) Minimize Cost (34%); (8) Coordinate Project (33%); (9) Install New Tools and Equipment (33%); (10) Administration (32%); (11) Review Problems with Vendors (30%); (12) Order from Vendors (24%); (13) Plant Layout (23%); and (14) Numerical Control (9%) (Little, 1968, p. 7). Additionally, manufacturing engineers were asked which three areas of competence (1) were most used in everyday work, and (2) were they planning to obtain more training in the next five years. The results were:

A. Every Day Work:

1. Design of Tooling
2. Administration

3. Supervision

B. Additional Training:

1. Numerical Control

2. Manufacturing Management

3. Administration (Little, 1968, p. 91)

At the Eighth Annual Tri-Service Manufacturing Technology Advisory Group Meeting, held in Arlington, Texas (1976), a joint presentation by the American Defense Preparedness Association (ADPA) and The Society of Manufacturing Engineers (SME) reviewed the projected technology needs of U.S. industry by 1980 to 1990. Those technological competencies which were identified as being important to utilize in manufacturing included: (1) Robotics; (2) Energy Conservation; (3) Automation; (4) CAD/CAM; (5) Group Technology; (6) Joining Processes; and (7) Composite Manufacturing.

In 1976, the Society of Manufacturing Engineering Processes Group compiled a "Directory of Manufacturing Research Needed by Industry." In addition to conventional engineering training, the study suggested research topics which would be of great interest to the manufacturing industry. Some of these technical competencies include the following: (1) Manufacturing with Minimum Energy Consumption; (2) Packaging and Shipping; (3) Lubricants; (4) Metal Forming; (5) EDM Metal Removal Mechanism; (6) Plastics Bright Finishes; (7) Cutting Tool Materials and Operation; (8) Non-human Optical Inspection Techniques; (9) Automatic Parts Feeding; and (10) Stack Gas Treatment.

Merchant (1976) obtained a concensus from a Delphi-type forecast which indicated a strong direction towards computer controlled factory operations. As a forecasting technique, the Delphi method attempts to identify future events utilizing a group of experts. The future manufacturing engineering activities which were suggested to be emphasized in education included: (1) group technology or cellular manufacturing; (2) job enrichment; (3) worker productivity improvement; (4) participative factory management; (5) worker safety; (6) computer-controlled factory operations; (7) modular manufacturing software system development.

In a joint effort, SME (Society of Manufacturing Engineering) in conjunction with the University of Michigan (1977), undertook a Delphi-type survey to determine the anticipated directions in manufacturing technology and management. The panelists were managers and engineers in metal working companies located in North America which provided a cross-section of manufacturing industries. Some of the conclusions were that greater engineering competence in the following areas would be increasingly important in manufacturing: (1) composite materials; (2) computerized planning, control and manufacturing; (3) numerical control; (4) computer software for automation; (5) group technology; (6) lasers; (7) machine design with computer graphics; (8) noise reduction; (9) mini- and microcomputer systems; (10) laser use in-process control; (11) production of dies directly from styling graphics to N/C machine tools; (12) CAD of ECM and EDM tooling; (13) sensors and sensing systems; and (14) high speed, closed loop inspection systems. It was stressed that a cooperative effort between industry, universities and government is needed to meet future demands in manufacturing. It was also stressed that there is a trend toward computer usage in manufacturing and the need for a systems oriented manufacturing engineer.

A study conducted by Battelle/Columbus Laboratories (1979), updated the Little report on manufacturing engineering. The survey utilized a questionnaire which identified the characteristics of the respondents; the respondent's company; the respondent's place in his/her company; areas of competence used in everyday work; the areas of competence in which the respondents planned to obtain additional training; and the education and training practices of the engineer and employer. The questionnaire was mailed to 6,558 persons representing a stratified random sample of manufacturing engineers. In addition, 62 educators and 48 industrial leaders were involved in either interviews or responding to questionnaires.

Major conclusions drawn from the data obtained indicated that areas of competence included administration, tool design, supervision, manufacturing planning, manufacturing management, communications, human relations, safety, energy, environmental impact, finance, product liability and government regulations. Those areas where the greatest changes are expected include:

(1) The continued expansion of applied computer-oriented technology to manufacturing.

(2) The automation of groups of operations in manufacturing, together with automated assembly, automatic inspection, and the application of adaptive controls and diagnostics, leading ultimately to the computer-integrated factory.

(3) Group technology.

(4) Expanded use of lightweight materials in products.

(5) Development of energy-efficient manufacturing methods.

(6) Compliance with regulatory or legal requirements relating to:

(a.) Product safety and liability

(b.) Worker hazards

(c.) Manufacturing wastes, effluents, and emissions.

(7) Job responsibilities of the manufacturing engineer.

(8) Job enrichment in the manufacturing industry.

(9) Utilization and coordination of satellite and/or international operations. (Battelle, 1979, p. 57)

The report stressed the need for manufacturing engineering graduates to have a sound foundation in engineering science; broad familiarity with manufacturing processes; well trained in theory, design and material science; possessing communication skills (both written and oral); and having practical experience. The tendency is for manufacturing engineers to move towards management and systems engineering functions.

Related Methodological and Statistical Studies

A study was conducted by Moon, (1968), which provided assistance for the development of an improved industrial arts and laboratory to reflect the industrial technology. Through the results obtained by a mail survey, the following were identified: (1) the principle process operations of manufacturing industries in the state of Oregon; (2) the commonality existing between various industrial classifications and the process operations they perform; (3) the methodology utilized to perform the process operations; (4) the process operations which should become curricular components of the industrial arts curriculum; and (5) the type of laboratory which would be needed to implement the new curriculum defined in 1 through 4 above. The survey instrument was developed without the utilization of a jury of experts nor the consultation of an advisory board.

Participants in the study were selected from 12 of the 21 major Standard Industrial Classifications in manufacturing on the basis of their size (in number of employees) and diversity of manufactured products. Five hundred and ninety-nine establishments were contacted and 362 (72.9%) returned the completed questionnaire. The study analyzed a broad sampling of manufacturing firms so that the results would truly represent manufacturing in the state of Oregon. Although not a random sample, it was felt that each industrial classification was substantially represented. The analysis of the study was limited to the use of descriptive statistics such as numbers and percentages.

Recommendations which evolved from the study included the proposition that industrial arts curriculum should not only be oriented to the materials of industry but also to the technological concepts which are related to the industrial processes. These processes include forming, casting/molding, shaping, assembly and auxillary operations. It was felt that this would require the use of a multipurpose laboratory providing a wide range of activities in both processes and materials.

In a study which provided data to help educators plan engineering eduation in Arizona, Lee (1968), conducted an industrial survey to answer the following questions: (1) What kinds of educational programs are needed to provide students for engineering, technical, and skill industrial employment?; (2) Should new curricula be designed to educate students for new combinations in the engineering profession?; and (3) Can experience and professional judgment of persons on the job help educators in efforts to produce better trained and educated persons?

Survey questionnaires were constructed with the assistance of two review panels made up of key educators throughout the state. The survey involved 610 employers representing 33 Standard Industrial Classifications. A total of 13,589 questionnaires were distributed with 3,926 (29%) of them being returned. Every employer of engineers or technical personnel in Arizona who could be identified were contacted and asked to participate.

The results were presented in percentages of responses to each question in each classification. Findings which evolved included the need for cooperative school-industry programs; more modernized courses/machinery; more manufacturing processes, industrial engineering and supervision/administrative preparation; and better counseling (educational planning) of the students during their schooling years.

In determining the educational needs of industrial technologists in the automotive-type manufacturing industries, Hall (1970) mailed questionnaires to 101 establishments throughout the United States. Multiple classification analysis of variance was used along with other descriptive statistical methods to analyze the 67 (66.3%) returned surveys.

Findings from this study suggest that the employment requirements are similar throughout the automotive manufacturing industries. It was also determined that there were specific subject areas along with practical work experience. Of noteworthy concern was the opinion that Higher Education was doing an incomplete job of training and education of industrial technologists except in the areas of mathematics and science.

In a study outside the realm of manufacturing, Miller (1971) determined the professional educational competencies of selected vocational instructors as identified by instructors in business and distributive education. A mail survey questionnaire containing 99 competencies was constructed and validated through a review of literature, evaluation by a jury of experts, and a field test. A five-point Likert-type scale was used in the survey to categorize responses. The random sample of 160 instructors in four western states provided the data which was analyzed using the F statistic to determine if significant differences existed between the community colleges. Factor analysis was also utilized to order and cluster competencies according to respondents. The analysis of variance tests indicated that community colleges were alike in their responses to the competencies and that 91 of 99 competencies required a moderate to high level of proficiency.

Stamps' (1979), conducted a study to determine common personal finance competencies needed by graduating high school students in Oregon. A questionnaire was developed and validated by a jury of experts and field tested with members of the business community and teachers of personal finance. The questionnaire contained 70 competencies using a five-point Likert-type scale and were sent to a random sample of personal finance teachers and members of the business community.

The data was statistically analyzed using the one-way analysis of variance and factor analysis resulting in the determination that 49 competencies were desirable and 21 competencies were considered to be of moderate value. Major differences existed between the business community and the personal finance teachers, while less difference existed among the teachers from the four subject matter areas chosen for the study. The final recommendation was that all competencies in the study should be included in Oregon's personal finance curriculum.

Summary

The utilization of personnel in industry to evaluate educational competencies is an acceptable technique in curriculum development. These competencies can be presented as subject matter areas of which an assessment can be made as to the level of knowledge required in that area. Using a jury of experts in industry to evaluate and help construct a questionnaire containing these competency areas has proven to be an effective procedure in recent studies. Additionally, the use of knowledgeable populations, not necessarily random samples, to obtain data with which to statistically analyze and base curriculum decision-making upon, is supported. It is evident that regional areas will vary in the types of manufacturing most prevalent and that regional studies have been conducted to access these variances. In manufacturing engineering education, additional investigation is needed so that it can be further defined what the requirements of manufacturing engineers will be upon graduation in the state of Oregon.

III. DESIGN OF THE STUDY

This study investigated manufacturing engineering knowledge requirements to provide information for the design and development of the manufacturing engineering curricula at Oregon State University.

Preparation of the Instrument

The instrument used in this study was a mail survey questionnaire containing 56 manufacturing engineering competencies utilizing a five-point Likert scale. This five-point Likert scale allowed each respondent to judgementally evaluate the level of knowledge required in the various competency areas.

The development of the survey instrument was achieved by a review of studies by Lindberg (1975), Lee (1968), Stamps (1979), and Little (1968), along with miscellaneous publications from the Society of Manufacturing Engineers. This information was compiled into a preliminary listing of manufacturing competency areas.

The preliminary listing was presented to a jury of experts who suggested revisions in its content. The six-person committee (Appendix A) was composed of manufacturing engineering representatives from industry and education in the state of Oregon. The jury of experts' revision form and preliminary listing is found in Appendix B.

The results from these revisions and the instrument developed by Lee (1968) provided the base for the manufacturing engineering questionnaire. This questionnaire and the cover letters were forwarded to each member of the jury of experts for the purpose of establishing validity to the instrument. Each member was asked, over the telephone, to review the questionnaire and to note any recommendations or suggestions for revision.

There were no revisions and those members of the jury who represented industry were requested to complete the questionnaire. This step provided a modified field testing method as all of the industrial jury members were managers of manufacturing.

The Dependent Variable

The dependent variable in this study was the score assigned by the respondents to each competency item indicating the level of knowledge required. Respondents were asked to make a judgmental evaluation as to the level of knowledge required in each of the 56 competency areas based on their own experience. Each of the 56 competencies were assigned a score for the level of knowledge required in each of the 56 competency areas based on their own experience. Each of the 56 competencies was assigned a score for the level of knowledge required using the following Likert-type scale: 1. Not necessary; 2. Minimal; 3. General; 4. Substantial; 5. Advanced.

Selection of the Sample

The population from which the sample for this study was derived, consisted of those manufacturers listed in the Directory of Oregon Manufacturers, 1978, published by the State of Oregon Department of

Economic Development. The directory contains information pertaining to products, employment figures and locations for approximately 4600 manufacturing firms in Oregon.

In a similar study by Moon, (1968), this sampling technique was utilized using the product listing portion of the directory. This includes the following information: 1. the name of the company; 2. its principle product; 3. the number of employees; and 4. the principle company official. Utilizing the four-digit code numbers which the product listing is organized, Moon used these Standard Industrial Classification (S.I.C.) codes established by the United States Bureau of the Budget to identify and separate the various product lines of the differing manufacturing plants. This same technique will be used in this study.

The Standard Industrial Classifications, as listed in the directory, contain 19 separate categories, of which not all are acceptable to this study. In order to eliminate Industrial Classifications not suitable, the following criteria for the selection was established:

1. The classifications were not represented by manufacturing establishments in Oregon.

2. The establishments listed employed less than 100 employees.

Standard Industrial Classifications (S.I.C.)

Code	Classification
2000	Food and Kindred Products
2200	Textile Mill Products
2300	Apparel and Other Finished Products

Code	Classification
2400	Lumber and Wood Products (except furniture)
2500	Furniture and Fixtures
2600	Paper and Allied Products
2700	Printing, Publishing and Allied Products
2800	Chemicals and Allied Products
2900	*Petroleum Refining and Related Industries
3000	Rubber and Miscellaneous Plastic Products
3100	*Leather and Leather Products
3200	Stone, Clay, Glass and Concrete Products
3300	Primary Metals Industry
3400	Fabricated Metal Products, (not elsewhere classified) and Transportation Equipment
3500	Machinery, except Electrical
3600	Electrical Machinery, Equipment and Supplies
3700	Transportation Equipment
3800	Measuring, Analyzing, and Controlling Instruments; Photographic and Optical Goods; Watches and Clocks
3900	Miscellaneous Manufacturing Industries

*Classifications not suitable for this study

From the approximately 4600 manufacturing industries listed in the Directory, 428 firms, or approximately nine percent, were suitable for this study. All 428 manufacturing firms were chosen to be participants for the study.

The Statistical Design

The major focus of this study was to determine the level of knowledge required in 56 manufacturing engineering competencies for use in curriculum planning at Oregon State University. This section describes the statistical procedures used to test the hypothesis which deals with determining the level of knowledge required in various competency areas as described by manufacturing managers. Research by Siewart, (1978); Spaziani, (1972); Gunderson, (1971); Lindahl, (1971); and Stamps, (1979), provide the base for the design of this study.

1. It was desirable to identify a universal competency mean score for the level of knowledge required in each of the 56 competency areas so that recommendations could be drawn as to which areas should be emphasized in curriculum development.
   A. Means for acceptance of content were computed by assigning a weight of: 1. for Not Necessary; 2. for Minimal; 3. for General; 4. for Substantial; and 5. for Advanced. Competencies were placed in rank order by means with those rated advanced first.
2. It was desirable to identify the various competency mean scores in the various Standard Industrial Classification categories so that specific needs might be identified for various manufacturing applications.

The hypothesis tested in this study was that there was no significant difference in the level of knowledge required in the manufacturing engineering competencies among the manufacturing firms as identified by manufacturing managers in the 17 Standard Industrial Classifications studied.

$$Ho = \mu_1 + \mu_2 + \mu_3 + \mu_4 + \mu_5 + \mu_6 + \mu_7 + \mu_8 + \mu_9 + \mu_{10} + \mu_{11} + \mu_{12} + \mu_{14} + \mu_{15} + \mu_{16} + \mu_{17}$$

The one-way analysis of variance was utilized on each of 56 competencies identifying the levels of knowledge required.

The analysis of variance arrangement used to study each of the 56 competencies is shown in Table 1.

TABLE 1. Analysis of Variance Layout

Source of Variance	Adj. df	Adj. SS	Adj. MS	Adj. F
Between Groups	16	A	A/16	MS Bet/MS Error
Within (error)	142	B	B/142	
Total	158	C		

The F Statistic was utilized to test the significance among means. The acceptance or rejection of the null-hypothesis was based on the selected .05 level of significance.

Critical $F\alpha$ = .05 df = 16, 142 $\geq$ 1.717

If computed F $\geq$ 1.717; Rejected Ho

If computed F $\leq$ 1.717; Retain Ho

Ho = There is no significant difference between the 17 classifications of manufacturing manager's assessment of the level of knowledge required in the competency area.

Ha = There is a significant difference between the 17 classifications of manufacturing manager's assessment of the level of knowledge required in the competency area.

Collection of Data

The following steps were utilized in the collection of data:

1. The Oregon SME (Society of Manufacturing Engineers) Chapter 63 provided a cover letter for the instrument as did the Head of the Department of Industrial and General Engineering at Oregon State University which endorsed the study and its importance in planning curriculum.
2. In addition to the two cover letters, the instrument was mailed to managers of manufacturing with an explanation of the purpose of the request, how the data obtained would be used, and why it was necessary for their participation.
3. The final questionnaire was mailed to the 428 manufacturing firms with the instruments being coded for a follow-up of unanswered questionnaires. Respondents were assured that all responses were held in strict confidence, that the responses would be recorded and

analyzed as a group, and that results of the study would be available on request.

4. To increase the rate of response from the sample group, a follow-up post card reminder was mailed two weeks following the initial mailing to those who had not responded.

5. The collected data was checked to insure completeness and clarity of markings. The data from each questionnaire was punched and verified at the Oregon State University Computer Center.

IV. PRESENTATION OF FINDINGS

The analysis of data for the study is presented in three sections. The first section describes the sample involved in the study. The second section presents the results of the mean-ranking of competency areas. The third section presents the results of the analysis of variance which identified significant differences among the competency area mean scores of the 17 major industrial classifications involved in the study and also identified where those significant differences existed.

Sample

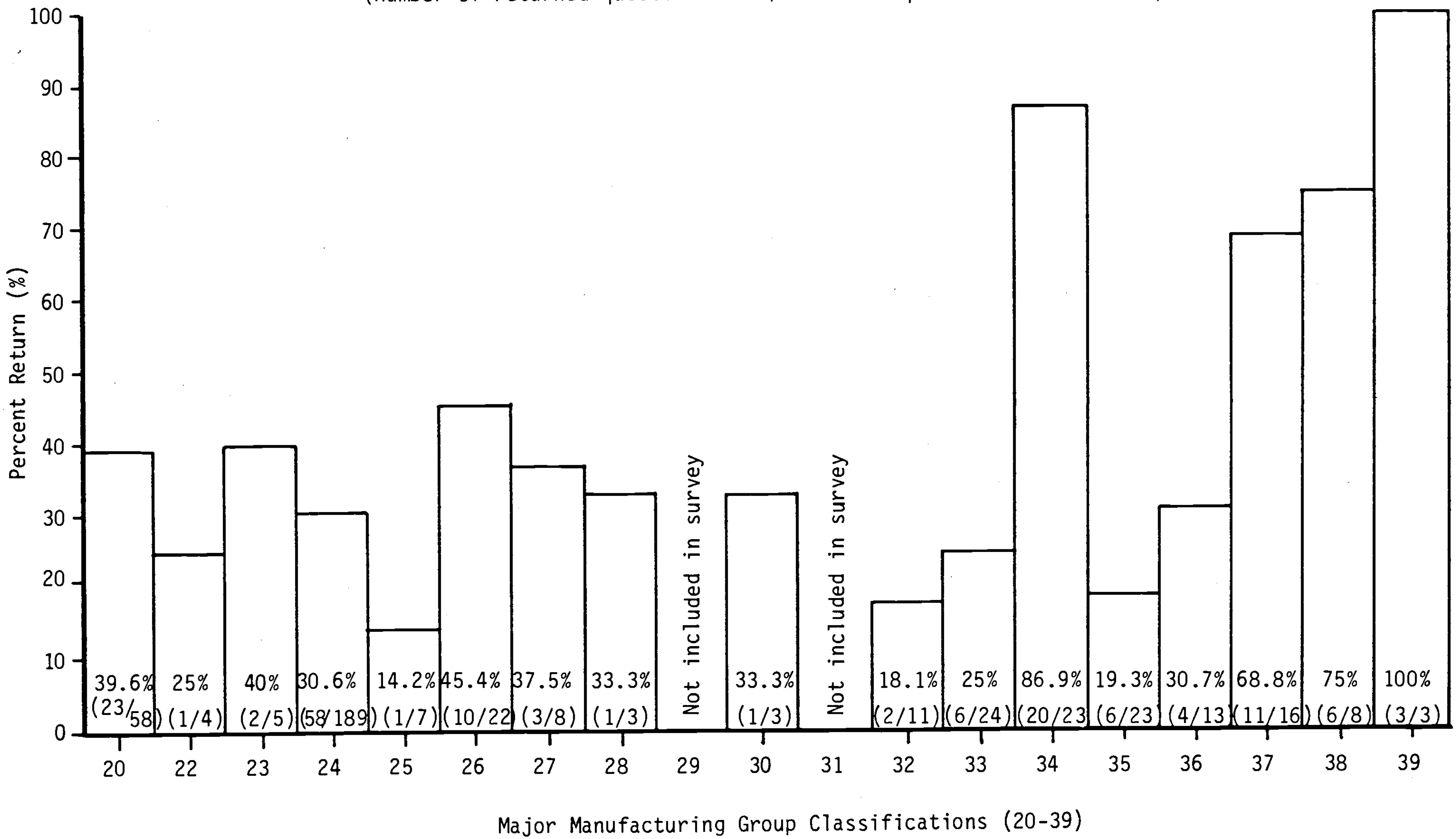
Of the 428 manufacturing managers who were mailed questionnaires, 158 (36.9%) responded, representing all of the major industrial classifications found suitable for the study. Chart 1 presents the percentage of returns by the major industrial group classifications and also identifies the actual number of returns compared with the number of questionnaires mailed.

Of those managers of manufacturing who did respond, the following group classifications represented the highest and lowest percent returns: miscellaneous manufacturing industries (100%); fabricated metal products (86.9%); measuring, analyzing, and controlling instruments (75%); and transportation equipment (68.8%) represented the highest percentages of returns, while furniture and fixtures (14.2%); stone, clay, glass and concrete products (18.1%); and machinery (except electrical) (19.3%)

Chart 1

Percent (%) Return by Manufacturing Group Classifications

(Number of returned questionnaires/number of questionnaires mailed)



represented the lowest percent returns of those who were mailed questionnaires.

Chart 2 represents the geographical locations of the various respondents by counties in the state of Oregon. Those counties with the greatest number of participants in the study included: Multonomah (33); Washington (15); Linn (13), Clackamas (11); Douglas (11); and Lane (10). Those counties that were not represented included: Gilliam; Jefferson; Malheur; Morrow; Sherman; Wallowa; Wasco; and Wheeler.

The variance among the sizes of the companies ranged from 100 employees to 9200 employees. Of the 158 companies involved in the study, 42 percent employed 100-199 persons; 23 percent employed 200-299 persons; 12 percent employed 300-399 persons; 5 percent employed 400-499 persons; 6 percent employed 500-749 persons; 3 percent employed 750-999 persons; 5 percent employed 1000-1499 persons; 2 percent employed 1500-1999 persons; and 2 percent employed 2000 or more persons.

Results of the Mean-Ranking

Each of the 56 competency areas was ranked by the level of knowledge required. Rankings were based on the overall mean scores of each of the competency areas determined by all of the participants in the study. These 56 competency areas are presented in Table 2. The overall means compared to major competency area category is illustrated in Chart 3.

Respondents were asked to identify the level of knowledge required in the manufacturing engineering competencies needed by graduating manufacturing engineering students using the following categories:

Chart 2 - Geographic Location of Survey Respondents By Number of returned surveys in each county in the State of Oregon (n=158)

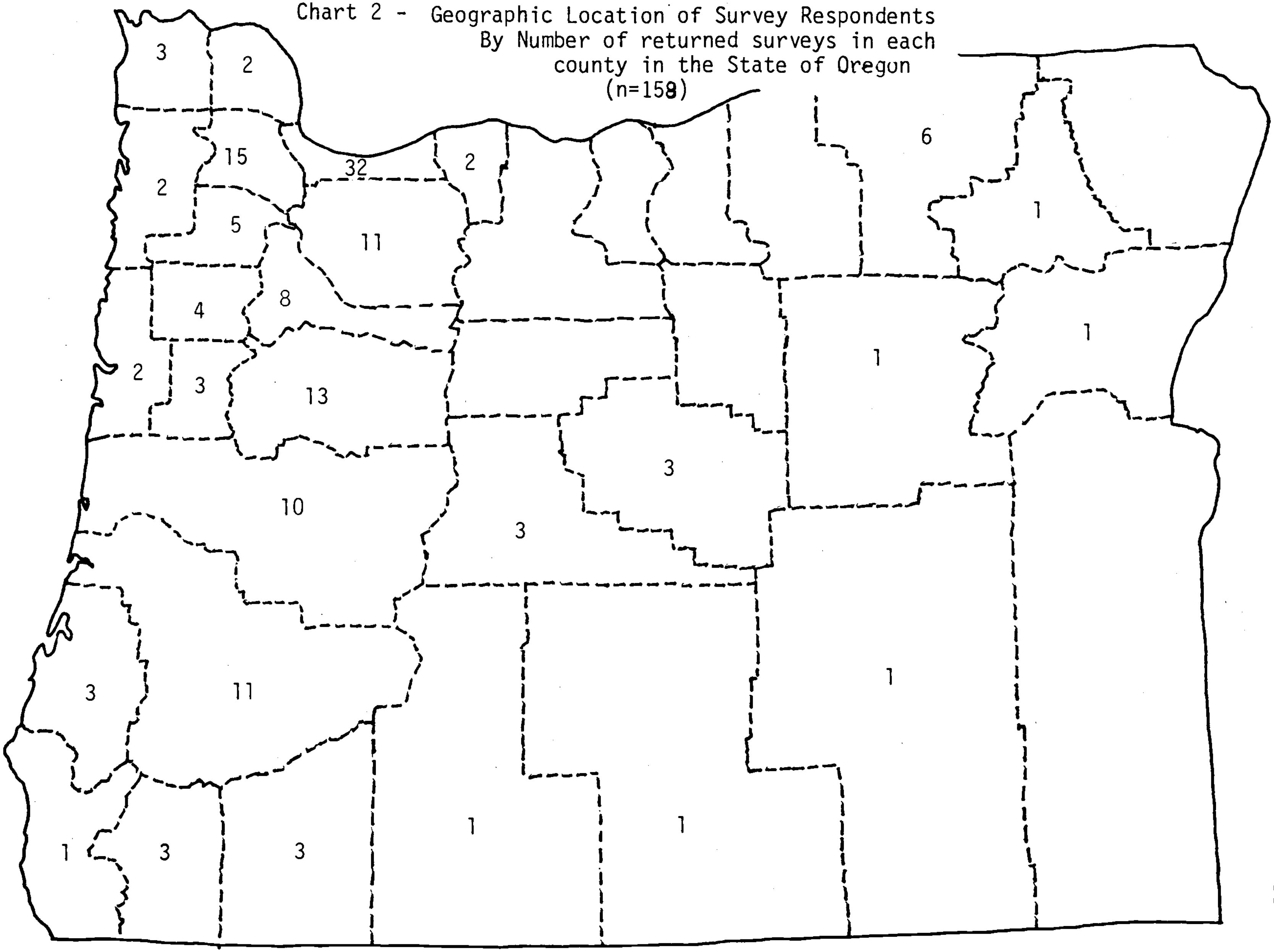


TABLE 2. Order of Importance of Manufacturing Engineering Competencies for Level of Knowledge by all Manufacturing Classifications.

Mean Ranking	Item #	Title of Competency	Mean	Standard Deviation
1	52	Energy Conservation	3.8153	.8535
2	49	Expenditure Justification/Reduction	3.7771	.7035
3	19	Hydraulics/Pneumatics	3.7673	.8509
4	20	Electricity/Electronics	3.7421	.8360
5	43	Work Design; Methods/Motion	3.7325	.8652
6	42	Production Control Systems	3.7261	.7391
7	51	Safety	3.7197	.7666
8	45	Supervision	3.6859	.7936
9	22	Metals	3.6792	.8216
10.5	53	Production Planning/Scheduling	3.6433	.7927
10.5	41	Facilities Planning	3.6433	.8087
12	56	Engineering Economics	3.6218	.7898
13	46	Job Design/Motivation	3.5897	.7859
14	36	Product Engineering for Manufacturing	3.5833	.8029
15	1	Oral Communication (Speaking)	3.5823	.5199
16	47	Management Systems/Techniques	3.5548	.7038
17	50	Cost Estimating/Accounting	3.5478	.7463
18	14	Physics	3.5346	.8251
19	29	Assembly Methods (Adhesives, Fasteners, Joining)	3.5283	.9468
20	3	Report Writing	3.5127	.6358
21	31	Material Removal Methods (Machining)	3.5031	.9928
22	16	Metallurgy	3.4591	.9727
23	23	Plastics	3.4395	.7035
24	44	Engineerin Graphics/Design	3.4231	.8194
25	17	Statics/Dynamics	3.4214	.8448
26	18	Material Science	3.4151	.8058
27	37	Computer Applications/CAM	3.4013	.9260
28	32	Material Forming Methods (Forging, Bending)	3.3899	.9931

Mean Ranking	Item #	Title of Competency	Mean	Standard Deviation
29	7	Economics (Macro/Micro)	3.3885	.7130
30	2	English Composition (Writing)	3.3671	.5683
31	35	Tool Materials/Engineering	3.3503	.8761
32	54	Inventory Control	3.2930	.7947
33	21	Thermodynamics	3.2548	.8216
34	15	Chemistry	3.2075	.8864
35	11	Calculus	3.1962	.8991
36	55	Operations Research Techniques	3.1859	.7344
37	23	Plastics	3.1772	.7942
38	33	Finishing Methods (Coating, Plating)	3.1592	.9234
39	40	Factory Automation (Robotics)	3.1154	.9769
40	24	Wood	3.0823	.9575
41	13	Linear Equations and Matrices	3.0696	.9518
42	12	Differential Equations	3.0629	.9526
43	38	Computer Simulation/CAD	3.0382	.9260
44	30	Casting/Molding Methods	3.0063	1.0403
45	8	Psychology	2.9873	.7400
46	28	Cement/Concrete	2.9241	.9547
47	39	Computer Languages/Software	2.9221	.8969
48	34	Non Traditional Methods (EDM, Lasers)	2.8710	.9650
49	27	Rubber	2.6497	.8310
50	6	Sociology	2.4904	.8056
51	25	Ceramics	2.4808	.8460
52	26	Glass	2.3671	.8548
53	9	Philosophy	2.1824	.7701
54	5	Political Science	2.1203	.7081
55	4	History	2.0823	.6480
56	10	Fine Arts	1.8089	.7436

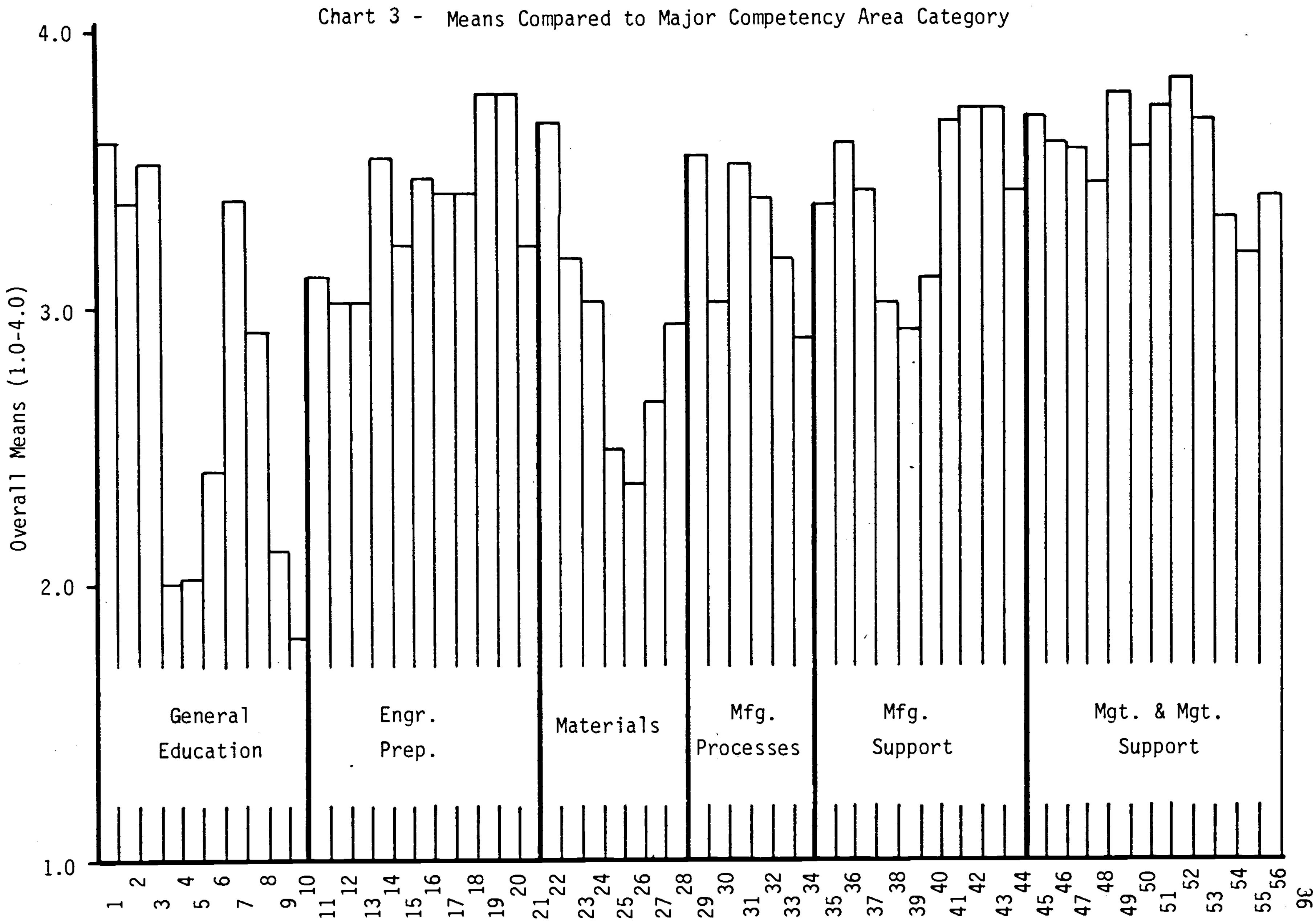


Chart 3 - Means Compared to Major Competency Area Category
Overall Means (1.0-4.0)
4.0
3.0
2.0
1.0
General Education
Engr. Prep.
Materials
Mfg. Processes
Mfg. Support
Mgt. & Mgt. Support
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56

1, not necessary; 2, minimal; 3, general; 4, substantial; and 5, advanced.

Of the 56 manufacturing engineering competencies ranked by all 17 major industrial classifications, none had means of 4.0 or above; 21 had means between 3.5 and 4.0; 23 had means between 3.0 and 3.5; 5 had means between 2.5 and 3.0; 6 had means between 2.0 and 2.5; and 1 had a mean of less than 2.0.

The ten highest overall mean ranks in descending order included: (1) energy conservation (3.8153); (2) expenditure justification/reduction (3.7771); (3) hydraulics/pneumatics (3.7673); (4) electricity/electronics (3.7673); (5) work design methods/motion (3.7325); (6) production control systems (3.7325); (7) safety (3.7197); (8) supervision (3.6859); (9) metals (3.6792); and (10) production planning/scheduling (3.6433); (11) facilities planning (3.6433). The ten lowest mean ranks included: (1) fine arts (1.8089); (2) history (2.0823); (3) political science (2.1203); (4) philosophy (2.1824); (5) glass (2.3671); (6) ceramics (2.4808); (7) sociology (2.4904); (8) rubber (2.6497); (9) nontraditional methods (2.8710); and (10) computer languages/software (2.9221). Table 3 presents the rank order for the five highest and lowest competency area means by each of the major industrial classifications who were represented by two or more participants in the study.

TABLE 3. The Rank Order for the Five Highest and Lowest Competency Area Means by Each of the Major Industrial Classifications

1. Food and Kindred Products

Highest			Lowest		
Rank	Mean	Competency Area	Rank	Mean	Competency Area
1	4.3182	Energy Conservation	56	1.8696	Fine Arts
2	4.0000	Hydraulics/ Pneumatics	55	2.0870	History
3	3.8636	Expenditure Justification	54	2.2174	Political Science
4	3.8261	Physics	54	2.2174	Philosophy
5	3.8182	Supervision	53	2.3636	Non-traditional Methods

2. Apparel and Other Finished Products

Highest			Lowest		
Rank	Mean	Competency Area	Rank	Mean	Competency Area
1	5.0000	Work Design	56	1.5000	History
2	4.5000	Product Engr. for Mfg.	56	1.5000	Fine Arts
2	4.5000	Job Design/Motivation	56	1.5000	Metallurgy
2	4.5000	Expenditure Justification	56	1.5000	Hydraulics/ Pneumatics
3	4.0000	Oral Communication	56	1.5000	Thermodynamics
3	4.0000	English Composition	56	1.5000	Metal
3	4.0000	Psychology	56	1.5000	Plastic

Rank	Mean	Competency Area	Rank	Mean	Competency Area
3	4.0000	Assembly Methods	56	1.5000	Wood
3	4.0000	Facilities Planning	56	1.5000	Ceramics
3	4.0000	Production Control	56	1.5000	Glass
3	4.0000	Supervision	56	1.5000	Rubber
3	4.0000	Cost Estimating	56	1.5000	Cement/Concrete
3	4.0000	Production Planning	56	1.5000	Casting/Molding
3	4.0000	Inventory Control			
3	4.0000	Engineering Economics			

3. Lumber and Wood Products

Highest			Lowest		
Rank	Mean	Competency Area	Rank	Mean	Competency Area
1	3.9153	Energy Conservation	56	1.8246	Fine Arts
2	3.8664	Production Control	55	2.1552	History
3	3.8475	Hydraulics/Pneumatics	54	2.2414	Political Science
4	3.8305	Electricity/Electonics	53	2.2712	Philosophy
5	3.7966	Supervision	52	2.3220	Glass

4. Paper and Allied Products

Highest			Lowest		
Rank	Mean	Competency Area	Rank	Mean	Competency Area
1	4.2222	Energy Conservation	56	1.8000	Fine Arts

Rank	Mean	Competency Area	Rank	Mean	Competency Area
2	4.1111	Supervision	55	1.9000	History
3	3.9000	Hydraulics/ Pneumatics	54	2.0000	Philosophy
4	3.8889	Production Control	53	2.4444	Non-Traditional Methods
4	3.8889	Safety	52	2.5000	Sociology
4	3.8889	Engineering Economics			

5. Printing and Publishing and Allied Industries

Highest			Lowest		
Rank	Mean	Competency Area	Rank	Mean	Competency Area
1	4.3333	Electricity/ Electronics	56	1.3333	Glass
2	4.2222	Energy Conservation	55	1.6667	Ceramics
3	4.0000	Report Writing	55	1.6667	Fine Arts
3	4.0000	Economics	55	1.6667	Wood
3	4.0000	Computer Applications	55	1.6667	Rubber
3	4.0000	Expenditure Justification			

6. Stone, Clay and Glass

Highest			Lowest		
Rank	Mean	Competency Area	Rank	Mean	Competency Area
1	5.0000	Thermodynamics	56	2.0000	Fine Arts
1	5.0000	Cement/Concrete	55	2.5000	History
2	4.5000	Report Writing	55	2.5000	Political Science

Rank	Mean	Competency Area	Rank	Mean	Competency Area
2	4.5000	Physics	55	2.5000	Philosophy
2	4.5000	Electricity/ Electronics	55	2.5000	Factory Automation
2	4.5000	Metal			

7. Primary Metal Industry

Highest			Lowest		
Rank	Mean	Competency Area	Rank	Mean	Competency Area
1	3.9500	Work Design	56	1.8000	Fine Arts
2	3.8000	Material Forming	55	1.9000	Philosophy
3	3.7500	Product Engr. for Mfg.	54	1.9500	History
3	3.7500	Metallurgy	54	1.9500	Political Science
3	3.7500	Metals	53	2.3500	Sociology
3	3.7500	Expenditure Justification			

8. Machinery

Highest			Lowest		
Rank	Mean	Competency Area	Rank	Mean	Competency Area
1	4.3333	Material Removal	56	1.8333	Political Science
1	4.3333	Material Forming	55	2.0000	History
2	4.1667	Work Design	55	2.0000	Fine Arts
2	4.1667	Supervision	54	2.3333	Differential Eq.
2	4.1667	Expenditure Justification	54	2.3333	Linear Equations
2	4.1667	Assembly Methods			

9. Electrical Machinery, Equipment, and Supplies

Highest			Lowest		
Rank	Mean	Competency Area	Rank	Mean	Competency Area
1	3.7500	Report Writing	56	2.0000	Political Science
1	3.7500	Material Science	55	2.2500	Wood
1	3.7500	Metals	54	2.5000	History
2	3.5000	Oral Communications	54	2.5000	Philosophy
2	3.5000	English Composition	54	2.5000	Differential Equations
2	3.5000	Metallurgy	54	2.5000	Linear Eq.
2	3.5000	Statics/Dynamics	54	2.5000	Chemistry
2	3.5000	Hydraulics/Pneumatics	54	2.5000	Cement/Concrete
2	3.5000	Material Removal	54	2.5000	Finishing Methods
2	3.5000	Product Engr. for Mfg.			
2	3.5000	Facilities Planning			
2	3.5000	Production Control			
2	3.5000	Financial Analysis			
2	3.5000	Engineering Economics			

10. Transportation Equipment

Highest			Lowest		
Rank	Mean	Competency Area	Rank	Mean	Competency Area
1	4.3636	Mat'l Removal	56	1.8182	History

Rank	Mean	Competency Area	Rank	Mean	Competency Area
1	4.3636	Mat'l Forming	56	1.8182	Fine Arts
2	4.2727	Assembly Methods	55	1.9091	Sociology
3	4.1818	Metals	55	1.9091	Philosophy
4	4.0909	Metallurgy	54	2.0000	Political Science

11. Professional, Scientific, and Controlling Instruments; Photographic and Optical Goods; Watches and Clocks

Highest			Lowest		
Rank	Mean	Competency Area	Rank	Mean	Competency Area
1	4.1667	Electricity/ Electronics	56	2.0000	Fine Ats
1	4.1667	Mat'l Removal	55	2.1667	History
1	4.1667	Finishing Methods	55	2.1667	Cement/Con- crete
1	4.1667	Product Engr. for Mfg.	54	2.3333	Political Sci.
1	4.1667	Expenditure Jus- tification	53	2.5000	Philosophy

12. Miscellaneous Manufacturing Industries

Highest			Lowest		
Rank	Mean	Competency Area	Rank	Mean	Competency Area
1	4.3333	Work Design	56	1.6667	Fine Arts
2	4.0000	Physics	56	1.6667	Glass
2	4.0000	Metal	55	2.0000	Wood
2	4.0000	Assembly Methods	55	2.0000	Cement/Con- crete
2	4.0000	Product Engr. for Mfg.	55	2.0000	Computer Langu- ages

Rank	Mean	Competency Area	Rank	Mean	Competency Area
2	4.0000	Facilities Planning			
2	4.0000	Production Control			
2	4.0000	Expenditure Justification			

Analysis of Variance Techniques

The differences in judgments of the respondents about the level of knowledge required in the 56 manufacturing engineering competency areas were tested using the analysis of variance. The one-way analysis of variance using the F statistic tested the null hypothesis that there was no significant difference in mean scores as determined by the manufacturing community. A total of 56 individual hypotheses were tested, one for each competency area.

For 38 competency areas the computed F value was less than the critical value of 1.717 at the .05 level. The remaining 18 competency areas were equal to or greater than the critical value of 1.717 at the .05 level. Therefore, the null hypothesis was retained for 38 competency areas and rejected for 18 competency areas. Table 4 identifies those competency areas which were retained and rejected and the computed F value for each. For those competency areas rejected, the Student-Newman-Keuls procedure was utilized to compare the means of each group with the means of every other group. The 18 rejected competency areas, the mean ranking, the mean for each group, and the difference among groups as determined by the Student-Newman-Keuls procedure is shown in Table 5.

The following hypothesis was tested to determine if there were differences in judgments among the 17 major manufacturing industrial classifications: There are no significant differences among manufacturing managers in the 17 major industrial classifications on the judgment of the level of knowledge required in 56 manufacturing engineering

TABLE 4. Results of Analysis of Variance Using the F-Statistic for the Level of Knowledge (n=56)

Competency	Computed F	*Hypothesis
1	1.240	Retain
2	0.680	Retain
3	1.420	Retain
4	0.966	Retain
5	1.038	Retain
6	1.674	Retain
7	1.303	Retain
8	1.280	Retain
9	1.399	Retain
10	0.828	Retain
11	1.203	Retain
12	1.201	Retain
13	1.251	Retain
14	1.560	Retain
15	2.454	**Reject
16	1.931	**Reject
17	0.669	Retain
18	1.826	**Reject
19	2.038	**Reject
20	1.335	Retain
21	3.280	**Reject
22	1.981	**Reject

Competency	Computed F	*Hypothesis
23	1.397	Retain
24	7.480	**Reject
25	1.543	Retain
26	1.237	Retain
27	1.032	Retain
28	3.229	**Reject
29	1.723	**Reject
30	3.528	**Reject
31	2.240	**Reject
32	2.962	**Reject
33	2.711	**Reject
34	1.748	**Reject
35	1.984	**Reject
36	1.717	**Reject
37	1.338	Retain
38	1.142	Retain
39	0.995	Retain
40	1.285	Retain
41	0.636	Retain
42	0.949	Retain
43	1.243	Retain
44	1.223	Retain
45	1.552	Retain
46	1.806	**Reject

Competency	Computed F	*Hypothesis
47	0.775	Retain
48	1.611	Retain
49	1.663	Retain
50	1.313	Retain
51	0.466	Retain
52	2.473	**Reject
53	1.022	Retain
54	0.858	Retain
55	1.326	Retain
56	0.950	Retain

* The level of significance was .05 and the critical region with 16 degrees of freedom for the numerator mean square and 142 degrees of freedom for the denominator mean square was $F > 1.717$.

**The Student-Newman-Keuls procedure was used to compare means for the rejected items

TABLE 5. Results of Student-Newman-Keuls Procedure for the Rejected Hypothesis for the Level of Knowledge

Item #	Compentency	Ranking	Computed F **	Group 20 (n=23)	Group 23 (n=2)	Group 24 (n=58)	Group 26 (n=10)	Group 27 (n=3)	Group 32 (n=2)	Group 33 (n=6)	Group 34 (n=20)	Group 35 (n=6)	Group 36 (n=6)	Group 37 (n=11)	Group 38 (n=6)	Group 39 (n=3)	Significant Differences in means
				Mean Scores													
15	Chemistry	34	2.454	3.6522	2.0000	2.9661	3.8000	3.6667	4.0000	3.5000	3.1000	2.8333	2.5000	3.3636	3.5000	3.6667	*
16	Metallurgy	22	1.931	3.3478	1.5000	3.2712	3.4000	3.6667	4.0000	3.6667	3.7500	3.6667	3.5000	4.0909	3.6667	3.6667	11,6,8,13,12,9,7, 5,10,4,1,3,>2
18	Material Science	26	1.826	3.3913	2.5000	3.2712	3.7000	3.0000	4.0000	3.3333	3.4000	3.6667	3.7500	3.8182	3.8333	3.3333	*
19	Hydraulics/ Pneumatics	3	2.038	4.0000	1.5000	3.8475	3.9000	3.6667	4.0000	3.6667	3.5000	4.0000	3.5000	4.0000	3.3333	3.6667	11,9,6,1,4,3,13, 7,5,10,8,12,>2
21	Thermody- namics	33	3.280	3.7826	1.5000	3.2203	3.7000	2.3333	5.0000	3.1667	2.8500	2.8333	3.2500	3.5000	3.3333	3.3333	6,1,4,11,13,12,0, 3,7,8,9,5>2
22	Metals	9	1.981	3.4780	1.5000	3.5932	3.6000	3.6667	4.5000	4.1667	3.7500	3.8333	3.7500	4.1818	3.6667	4.0000	6,11,7,13,9,10,8, 12,10,3,7,8,9,5>2
24	Wood	40	7.480	2.8261	1.5000	3.7458	3.2000	1.6667	3.5000	3.5000	2.4211	2.6667	2.2500	2.3636	2.6667	2.0000	3,7,6,4,1,12,9,8, 11,10,13,5,3>2
28	Cement/ Concrete	46	3.2229	3.2174	1.5000	3.2373	3.2000	2.6667	5.0000	2.8333	2.4211	2.3333	2.5000	2.4545	2.1667	2.0000	6,3,1,4,7,5,10, 11,8,9,12,13>2
29	Assy.Methods	19	1.723	3.1739	4.0000	3.5085	2.9000	3.0000	3.5000	3.1667	3.6500	4.1667	3.2500	4.2727	4.0000	4.0000	11,9,13,12,2,8,3, 6,10,1,7,5>4
30	Mold/Casting	44	3.528	2.6522	1.5000	2.6610	2.8000	2.0000	3.5000	4.0000	3.6000	3.8333	3.0000	3.7273	3.8333	3.3333	*
31	Matl. Remov.	21	2.240	3.0870	2.0000	3.3390	3.3000	3.3333	4.0000	3.6667	3.7500	4.3333	3.2500	4.3636	4.1667	3.0000	*
32	Matl. Form.	28	2.962	3.0435	2.5000	3.2034	2.9000	2.6667	4.0000	3.5000	3.8000	4.3333	3.5000	4.3636	4.0000	3.0000	11,9,12,6,8,10,7, 3,1,4,5,2>13
33	Fin. Methods	38	2.7111	2.9091	2.0000	3.0339	2.8889	2.6667	3.5000	2.6667	3.5500	4.0000	2.5000	3.8182	4.1667	3.0000	*
34	Non-Tradi- tion Methods	48	1.748	2.3636	2.5000	2.9153	2.4444	3.0000	3.5000	2.6000	3.2000	3.2000	2.7500	3.0909	3.8333	2.6667	12,6,9,8,11,5,3, 10,13,7,2,4>1
35	Tool Engr.	31	1.984	3.0909	3.0000	3.3559	2.7778	2.3333	3.0000	3.0000	3.5500	3.8333	3.2500	4.0000	3.8333	3.6667	*
36	Proj. Engr.	15	1.717	3.3182	4.5000	3.6724	3.1111	3.6667	3.0000	3.0000	3.7500	3.3333	3.5000	3.9091	4.1667	4.0000	*
46	Job Design/ Motivation	14	1.806	3.7273	4.5000	3.7586	3.6667	3.3333	3.5000	3.3333	3.4500	3.8333	3.0000	3.0000	3.5000	3.0000	*
52	Energy Cons.	1	2.473	4.3182	2.0000	3.9153	4.2222	3.6667	3.5000	3.8333	3.4000	4.0000	3.0000	3.4545	3.5000	3.6667	1,4,9,3,7,13,5, 12,6,11,8,10>2

*While the F test determined a significant difference among groups, the Student-Newman-Keuls procedure did not define where the differences existed.

**The level of significance was set at the .05 level and the critical region with 16 degrees of freedom for numerator mean squares and 142 degrees of freedom for the denominator mean squares was F>1.717.

competency areas by manufacturing engineering students upon graduation. Of those competency areas ranked in the top ten, (1) energy conservation; (3) hydraulics/pneumatics; and (9) metals all had significantly different means assigned to them by manufacturing managers. In each case, the lowest mean score was given by the "Apparel and Other Finished Products" industrial classification. The Apparel and Other Finished Product classification represented the lowest mean score and was significantly different in seven of the ten competency areas where such a difference could be specifically identified by the Student-Newman-Keuls procedure. These competency areas included: (1) metallurgy; (w) hydraulics/pneumatics; (3) thermodynamics; (4) wood; (5) cement/ concrete; (6) metals; and (7) energy conservation. Competencies which had significant differences indicated by the F test but not verified by the Student-Newman Keuls test were the following: (15) chemistry; (18) material science; (30) casting/molding; (31) material removal; (33) finishing methods; (35) tool engineering; (36) product engineering; (46) job design/motivation.

V. SUMMARY, CONCLUSIONS AND IMPLICATIONS

Summary of the Study

The primary purpose for this study was to determine the acceptance and the level of knowledge required in various manufacturing engineering competency areas needed by graduating manufacturing engineering students in Oregon. This required determining the mean scores for the acceptance of content in various competency areas, to rank order them, and to determine if differences existed among the 17 major industrial classifications on the level of knowledge required in the 56 manufacturing engineering competency areas.

A mail survey questionnaire was developed to collect the data needed for the study. The questionnaire's development involved the interaction of professionals in the field of manufacturing engineering as well as a review of related literature. A preliminary listing of manufacturing engineering competency areas was developed reviewing literature in manufacturing, engineering, management and education. This preliminary listing was presented to a jury of experts who revised it, validating the content and clarifying its format.

The revised questionnaire was then field tested among a small sample of manufacturing managers. The final questionnaire contained 56 manufacturing engineering competency areas.

To determine the level of knowledge required in these areas, a five-point Likert-type scale was used consisting of not necessary, minimal, general, substancial and advanced as response selections.

The population of the study included all persons who were managers of manufacturing at companies with 100 or more employees in Oregon. This sample represented 428 manufacturing managers/firms in 17 industrial classifications. A follow-up postcard reminder was sent to each person utilized in the study who did not respond within a two week period of the first mailing. A total of 158 usable returned questionnaires were collected. The data obtained was mean-rank ordered and the one-way analysis of variance using the Student-Newman-Keuls procedure was utilized to determine if and where significant differences among mean scores existed.

Summary of the Findings

Results of the Mean Ranking

The data obtained from managers of manufacturing in the 17 industrial classifications utilized in the study established an overall mean for each of the 56 competency areas. These means were ranked from the highest mean score to the lowest mean score.

The competency area mean scores ranged from a high of 3.8153 to a low of 1.8089 with 21 having means between 3.5 and 4.0; 23 having means between 3.0 and 3.5; 5 having means between 2.5 and 3.0; 6 having means between 2.0 and 2.5; and 1 which had a mean of less than 2.0. The manufacturing engineering competency area which required the highest level of knowledge was the area of energy conservation.

Those competency areas which were ranked highest by the various industrial classifications included: (1) energy conservation (food and kindred products; lumber and wood products; paper and allied products); (2) work design; methods/motion (apparel and other products; fabricated metal products; miscellaneous manufacturing industries); (3) electricity/electronics (printing, publishing and allied industries; professional, scientific, and controlling instruments); (4) thermodynamics (stone, clay, and glass products; (5) cement/concrete (stone, clay, and glass products; (6) metals (primary metals industries; electrical, machinery, equipment, and supplies); (7) material removal methods (machinery; transportation equipment; professional, scientific, and controlling instruments); (8) material forming methods (machinery; transportation equipment); (9) report writing (electrical machinery, equipment, and supplies); (10) material science (electrical machinery, equipment, and supplies); (11) finishing methods (professional, scientific, and controlling instruments); (12) product engineering for manufacturing (professional, scientific, and controlling instruments); and (13) expenditure justification/reduction (professional, scientific, and controlling instruments).

Results of the One Way Analysis of Variance

To determine if significant differences existed between mean scores, the one-way analysis of variance tested the hypothesis that there was no significant difference in mean scores for the level of knowledge in 56 manufacturing engineering competency areas among managers of manufacturing in all 17 industrial classifications. The test indicated that there were no significant differences for 38 competencies and there were significant differences in 18 competency areas.

Of the 56 competency areas, 7 were significantly different out of the 21 that had overall means of 3.5 or above, 9 were significantly different out of the 23 that had overall means of 3.0 to 3.5; 2 were significantly different out of the 5 that had overall means of 2.5 to 3.0; and no competencies had significant differences out of the 7 that had overall means below 2.5. Therefore, the hypothesis that there was no significant difference among the mean score of the 17 industrial classifications was retained for 38 competency areas and rejected for 18 competency areas.

Conclusions

The question to which the study was directed was what level of knowledge in various manufacturing engineering competency areas are desirable for preparing students in manufacturing engineering education in the state of Oregon. The responses to each of the 56 competency areas were analyzed by the mean scores, the rank order of the means, and the analysis of variance test.

A total of 21 competency areas were identified by the sample as requiring "substantial" knowledge upon graduation while 28 were selected as requiring "general" knowledge. Seven competency areas were identified by the sample as "minimal" in the level of knowledge needed. The competency area category which the sample rated as needing the highest level of knowledge related to Management and Management Support. Engineering preparation, manufacturing support, manufacturing processes, materials, and general education represent the other competency area categories, being listed in decreasing amounts of knowledge required by the sample respondents.

Implications

The following implications have been developed from the review of the literature, the analysis of data, and the conclusions derived from this analysis. They are proposed as possible guidelines for manufacturing engineering curriculum development at Oregon State University and in the state of Oregon.

1. Competency areas perceived as requiring substantial knowledge (means in the range of 3.5 to 4.5) should be emphasized for curriculum planning in manufacturing engineering.
2. Competency areas perceived as requiring general knowledge (means in the range of 2.5 to 3.5) should be included in the manufacturing engineering curriculum.
3. Competency areas perceived as requiring minimal knowledge (means in the range of 2.5 or below) should not be emphasized for curriculum planning in manufacturing engineering.
4. Manufacturing engineering students should receive substantial background in management and management science.

5. The manufacturing engineering curriculum should be broad based, incorporating expertise from various disciplines such as business, engineering, economics, mathematics, behavioral sciences, and the pure sciences.
6. Flexibility should be integrated into a manufacturing engineering curriculum so that expertise can be developed in those competency areas which require substantial knowledge as identified by the various industrial classifications.
7. A manufacturing engineering curriculum should be developed through a cooperative effort between education, industry, government and the appropriate professional societies.

Suggestions for Further Study

The following are suggestions for further study:

1. The present study utilized a selected sample of manufacturing managers at manufacturing firms with 100 or more employees. A study which compared a random sample of manufacturing managers, engineers, educators and students should also be conducted. Firms over and under 100 employees could also be examined. This information would be invaluable in providing comparative data for making sound curriculum decisions.

2. Studies which include other competency areas, such as "statistics", or more specific abilities such as "knowledge of material requirement planning" should be conducted.
3. Studies to determine a more exact definition of manufacturing engineering should be undertaken. These definitions should differentiate between the type of education level (engineering, technology, or technician), experience, and other factors which are relevant.
4. Additional studies should be conducted to determine if manufacturing manager's demographic characteristics (number of years in management position, degree earned, age, geographic area where they work) effects or influences their opinions about manufacturing engineering competencies.
5. Studies should be undertaken which would determine the respondent's attitudes and understandings of the competency areas in manufacturing engineering.
6. Studies on the type of laboratory needs and equipment requirements, present and future, should be conducted to help educators plan for teaching, research, and above all, change.
7. The various methods of teaching manufacturing engineering should be studied. Different teaching methodologies may have differing effects on the learner's use of those competency areas taught.

8. Due to the dynamic nature of manufacturing engineering, education must also be dynamic by periodically evaluating and modifying competency area emphasis based upon studies such as this one.

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APPENDIX A

MANUFACTURING ENGINEERING ADVISORY COMMITTEE

MANUFACTURING ENGINEERING ADVISORY COMMITTEE

1979-80

Bill Sjoberg, Manager (Chairman)
Boeing Commercial Airplane Company
P.O. Box 20487
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Portland, OR 97220 (667-8517)

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APPENDIX B

JURY OF EXPERTS REVISION FORM

JURY OF EXPERTS REVISION FORM

From: ______________________ ______________________ ______________________
name position company

Subject: Suggested revisions to Manufacturing Engineering Competencies Listing.

Item	Omit	Revise	Retain	Suggested Revisions
<u>Manufacturing Processes</u>				
1. Assembly methods	1	2	3	____________
2. Casting methods	1	2	3	____________
3. Molding methods	1	2	3	____________
4. Material removal methods	1	2	3	____________
5. Material forming methods	1	2	3	____________
6. Finishing methods	1	2	3	____________
7. Metallurgical methods	1	2	3	____________
8. Exotic machining methods	1	2	3	____________
Suggested Additions				
<u>Materials</u>				
9. Metals	1	2	3	____________
10. Plastics	1	2	3	____________
11. Wood	1	2	3	____________
12. Ceramics	1	2	3	____________
13. Glass	1	2	3	____________
14. Rubber	1	2	3	____________
15. Composites	1	2	3	____________
Suggested Additions				
<u>Engineering Support</u>				
16. Engineering Materials	1	2	3	____________
17. Tool engineering	1	2	3	____________
18. Product Engineering	1	2	3	____________

Item	Omit	Revise	Retain	Suggested Revisions
Engineering Support Continued				
19. Computer-aided design	1	2	3	____________
20. Computer simulation t	1	2	3	____________
21. Computer languages/software	1	2	3	____________
22. Engineering graphics	1	2	3	____________

Suggested Additions

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Item	Omit	Revise	Retain	Suggested Revisions
Manufacturing Support				
23. Manufacturing control systems	1	2	3	____________
24. Factory automation	1	2	3	____________
25. Automatic assembly	1	2	3	____________
26. Computer-aided manufacturing	1	2	3	____________
27. Facilities planning	1	2	3	____________
28. Work design; methods/motion	1	2	3	____________
29. Material handling	1	2	3	____________
30. Quality assurance	1	2	3	____________
31. Robotics	1	2	3	____________
32. Group technology	1	2	3	____________

Suggested Additions

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Item	Omit	Revise	Retain	Suggested Revisions
Management and Management Support				
33. Supervision	1	2	3	____________
34. Job design/motivation	1	2	3	____________
35. Management systems/techniques	1	2	3	____________
36. Financial analysis	1	2	3	____________
37. Expenditure justification	1	2	3	____________
38. Cost estimating	1	2	3	____________
39. Safety	1	2	3	____________
40. Energy conservation	1	2	3	____________
41. Facilities planning	1	2	3	____________
42. Production planning/scheduling	1	2	3	____________
43. Inventory control	1	2	3	____________

Item	Omit	Revise	Retain	Suggested Revisions
Management and Management Support Continued				
44. Operations research techniques	1	2	3	____________________
45. Toxic substances	1	2	3	____________________
46. Noise control	1	2	3	____________________

Suggested Additions

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Additional Comments

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APPENDIX C

LETTER OF SUPPORT, DR. JAMES RIGGS

CHAIRMAN, DEPARTMENT OF INDUSTRIAL ENGINEERING
OREGON STATE UNIVERSITY

Department of Industrial & General Engineering
Oregon State University
Corvallis, Oregon 97331 (503) 754-4645

March 24, 1980

Dear Manager:

Please excuse the impersonal greeting. You deserve a more polite salutation because we are asking a favor of you. The favor impinges on your most precious resource--time--so, as one busy manager to another, I hope you can donate a few minutes from your schedule to participate in the attached survey.

We have recently introduced a new program for our engineering students. It is a manufacturing engineering option within the industrial engineering degree program. Mitch Nichols, the Coordinator of Manufacturing Engineering, is attempting to secure information from industrial sources that will be utilized in planning and operating the new curriculum. That is why we are seeking your help. We believe you are in a position to give us sound advice that will lead to a more effective program in manufacturing engineering.

In advance, thank you.

Yours sincerely,

James L. Riggs
Department Head

JLR:ss

enclosures

APPENDIX D

LETTER OF SUPPORT, FRANK GARDNER,

CHAIRMAN-ELECT, SOCIETY OF MANUFACTURING ENGINEERS, PORTLAND CHAPTER NO. 63

SOCIETY OF MANUFACTURING ENGINEERS
PORTLAND CHAPTER NO. 63
P.O. Box 14832
Portland, OR 97214

March 3, 1980

To: Manufacturing Executives

In order to make university programs more meaningful to students and industry, we want to take advantage of your expertise and practical experience in defining what students need to be competent in the area of manufacturing engineering.

The study that Mitchell Nichols is conducting regarding student competencies will have great value to the future planning of manufacturing engineering curriculum in the state of Oregon.

It is our hope that you will take the time to respond and send your answers to his questionnaire. Your views are extremely important if we are to study and meet the needs of manufacturing engineering in Oregon.

Chairman-elect

APPENDIX E

COVER LETTER FOR MANUFACTURING ENGINEERING QUESTIONNAIRE

Department of Industrial
& General Engineering

Oregon State University

Corvallis, Oregon 97331 (503) 754-4645

March 24, 1980

Dear Manager of Manufacturing:

As Coordinator of the Manufacturing Engineering Program at Oregon State University, I am conducting a study, with the help of the Department of Industrial Engineering, to determine the level of knowledge students will need in the various areas of manufacturing engineering. This information will assist us in preparing the best possible program for the students and industry.

Your help is needed. You, along with others from manufacturing based firms in Oregon, have been selected to complete this short questionnaire. It should only take a few minutes of your valuable time; and by doing so, you will have contributed greatly to the information needed to establish a quality manufacturing engineering educational program in the State of Oregon.

Responses to the questions will be recorded as a group and the coding in the upper right-hand corner of the questionnaire is solely for determining whether or not the questionnaire has been completed and returned. All responses will be held in strictest confidence. It would be greatly appreciated if you would return the questionnaire to me by April 25 in the pre-addressed, stamped envelope that is provided. Each completed questionnaire is important.

If you have any questions or concerns, please feel free to phone (754-2365) or write. Thank you.

Sincerely,

Mitchell R. Nichols
Manufacturing Engineering
Program Coordinator

MRN:ss

enclosures

APPENDIX F

MANUFACTURING ENGINEERING QUESTIONNAIRE

LEVEL OF KNOWLEDGE REQUIRED IN MANUFACTURING ENGINEERING COMPETENCY AREAS

Study Number ________

LEVEL OF KNOWLEDGE NEEDED IN MANUFACTURING ENGINEERING COMPETENCIES IN THE STATE OF OREGON

Research Project By: Mitchell R. Nichols
Department of Industrial and
General Engineering
Oregon State University
Corvallis, Oregon 97331

Purpose of the Questionnaire: The purpose of this questionnaire is to seek your assistance in providing your views, which will be useful in determining the level of knowledge required in various Manufacturing Engineering competency areas. This information will be used in planning the curriculum at Oregon State University in an effort to prepare students to meet their needs and industry's needs. Results of this study will be made available to you upon request.

INSTRUCTIONS FOR COMPLETING THE QUESTIONNAIRE

1. The questionnaire asks your opinion on the level of knowledge required in each of the 59 competency areas of Manufacturing Engineering.

2. DO NOT TAKE TOO MUCH TIME IN THINKING ABOUT ANY PARTICULAR ITEM. Please do not leave out any item. There are no right or wrong answers. The primary concern is about your judgement regarding the level of knowledge required in Manufacturing Engineering competencies needed by graduating Manufacturing Engineering students.

3. For each item, circle the rating (1, 2, 3, 4, 5) which most closely represents your judgement about the level of knowledge required. If your judgement is not precisely represented by one of the choices, pick the one which comes the closest. PLEASE COMPLETE ALL ITEMS.

   Example Only:

Competency Area	Level of Knowledge Required				
	Not Necessary	Minimal	General	Substantial	Advanced
A. Oral Communications (speaking)	1	2	(3)	4	5

In circling a "3" rating in the middle column, this person felt that a general level of knowledge in oral communications was required upon graduation as a Manufacturing Engineer.

REMEMBER: THIS IS NOT A TEST. COMPLETE ALL ITEMS. THANK YOU.

CONFIDENTIAL

Please check the one best classification which identifies your company. These Standard Industrial Classification Codes have been established by the U.S. Bureau of the Budget.

_____ 20. Food and Kindred Products

_____ 22. Textile Mill Products

_____ 23. Apparel and Other Finished Products

_____ 24. Lumber and Wood Products

_____ 25. Furniture and Fixtures

_____ 26. Paper and Allied Products

_____ 27. Printing and Publishing and Allied Industries

_____ 28. Chemicals and Allied Products

_____ 29. Petroleum Refinishing and Related Industries

_____ 30. Rubber and Miscellaneous Plastic Products

_____ 31. Leather and Leather Products

_____ 32. Stone, Clay, and Glass Products

_____ 33. Primary Metal Industries

_____ 34. Fabricated Metal Products (Not Elsewhere Classified)

_____ 35. Machinery (Except Electrical)

_____ 36. Electrical Machinery, Equipment, and Supplies

_____ 37. Transportation Equipment

_____ 38. Professional, Scientific, and Controlling Instruments; Photographic and Optical Goods; Watches and Clocks

_____ 39. Miscellaneous Manufacturing Industries

COMPETENCY AREA	LEVEL OF KNOWLEDGE REQUIRED				
General Education	Not Necessary	Minimal	General	Substantial	Advanced
1. Oral Communications (speaking)	1	2	3	4	5
2. English Composition (written)	1	2	3	4	5
3. Report Writing	1	2	3	4	5
4. History	1	2	3	4	5
5. Political Science	1	2	3	4	5
6. Sociology	1	2	3	4	5
7. Economics (Macro/Micro)	1	2	3	4	5
8. Psychology	1	2	3	4	5

COMPETENCY AREA	LEVEL OF KNOWLEDGE REQUIED				
	Not Necessary	Minimal	General	Substantial	Advanced
General Education (continued)					
9. Philosophy	1	2	3	4	5
10. Fine Arts	1	2	3	4	5
Engineering Preparation					
11. Calculus	1	2	3	4	5
12. Differential Equations	1	2	3	4	5
13. Linear Equations and Matrices	1	2	3	4	5
14. Physics	1	2	3	4	5
15. Chemistry	1	2	3	4	5
16. Metallurgy	1	2	3	4	5
17. Statics/Dynamics	1	2	3	4	5
18. Material Science	1	2	3	4	5
19. Hydraulics/Pneumatics	1	2	3	4	5
20. Electricity/Electronics	1	2	3	4	5
21. Thermodynamics	1	2	3	4	5
Materials					
22. Metals	1	2	3	4	5
23. Plastics	1	2	3	4	5
24. Wood	1	2	3	4	5
25. Ceramics	1	2	3	4	5
26. Glass	1	2	3	4	5
27. Rubber	1	2	3	4	5
28. Cement/Concrete	1	2	3	4	5
Manufacturing Processes					
29. Assembly Methods (Adhesives, Fasteners, Joining)	1	2	3	4	5
30. Casting/Molding Methods (Powder Metallurgy, Foundry)	1	2	3	4	5
31. Material Removal Methods (Machining)	1	2	3	4	5
32. Material Forming Methods (Forging, Bending, Shaping)	1	2	3	4	5

COMPETENCY AREA	LEVEL OF KNOWLEDGE REQUIRED				
	Not Necessary	Minimal	General	Substantial	Advanced
Manufacturing Processes (continued)					
33. Finishing Methods (Coating, Plating)	1	2	3	4	5
34. Nontraditional Methods (EDM, Lasers, ECM, etc.)	1	2	3	4	5
Manufacturing Support					
35. Tool Materials/Engineering	1	2	3	4	5
36. Product Engineering for Manufacturing	1	2	3	4	5
37. Computer Applications/Computer-Aided Manufacturing	1	2	3	4	5
38. Computer Simulation/Computer-Aided Design	1	2	3	4	5
39. Computer Languages/Software	1	2	3	4	5
40. Factory Automation (Robotics, etc.)	1	2	3	4	5
41. Facilities Planning	1	2	3	4	5
42. Production Control Systems	1	2	3	4	5
43. Work Design; Methods/Motion	1	2	3	4	5
44. Engineering Grahpics/Design	1	2	3	4	5
Management and Management Support					
45. Supervision	1	2	3	4	5
46. Job Design/Motivation	1	2	3	4	5
47. Management Systems/Techniques	1	2	3	4	5
48. Financial Analysis	1	2	3	4	5
49. Expenditure Justification/Reduction	1	2	3	4	5
50. Cost Estimating/Accounting	1	2	3	4	5
51. Safety	1	2	3	4	5
52. Energy Conservation	1	2	3	4	5
53. Production Planning/Scheduling	1	2	3	4	5
54. Inventory Control	1	2	3	4	5
55. Operations Research Techniques	1	2	3	4	5
56. Engineering Economics	1	2	3	4	5

APPENDIX G

POSTCARD USED FOR FOLLOW-UP

Dear Manager of Manufacturing:

Recently, a survey instrument was mailed to you asking your opinion on the level of knowledge required in 59 competency araes of manufacturing engineering. As of today, I have not received your completed questionnaire.

We need your valuable feedback to identify the requirements in industry of our future manufacturing engineers. The survey will take only a few minutes to complete and by doing so you will help to create a program which might meet your future engineering needs.

Thanking you in advance.

Oregon State University
Department of
Industrial & General
Engineering
Corvallis, Oregon 97331

Mitchell Nichols
Mfg. Engr. Coordinator