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A COMPARISON OF MANUFACTURING ENGINEERING TECHNOLOGY FACULTY AND MANUFACTURING MANAGERS ON ISSUES OF CURRICULUM

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has been accepted towards fulfillment of the requirements for

<u>PhD</u> <u>degree in College</u> and University Administration

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A COMPARISON OF MANUFACTURING ENGINEERING TECHNOLOGY FACULTY AND MANUFACTURING MANAGERS ON ISSUES OF CURRICULUM

By

Raymond W. Cross

A DISSERTATION

Submitted to Michigan State University in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Department of College and University Administration



ABSTRACT

A COMPARISON OF MANUFACTURING ENGINEERING TECHNOLOGY FACULTY AND MANUFACTURING MANAGERS ON ISSUES OF CURRICULUM

By

Raymond W. Cross

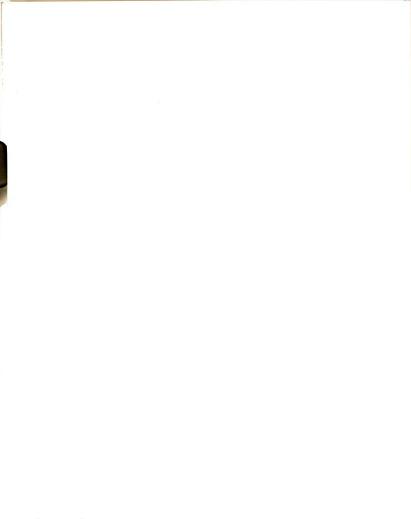
The purpose of this study was to determine if manufacturing engineering technology faculty differed with manufacturing managers in respect to the importance, level of instruction needed, and the future importance of the eleven subject areas identified in a Society of Manufacturing Engineers' curricula recommendation study. Five hundred manufacturing managers and 81 manufacturing engineering technology educators were surveyed using the same instrument.

Eleven major hypotheses, with three sub-hypotheses each, were developed to determine if the two groups differed over the importance, level of instruction needed, or the future importance of these subject areas in the manufacturing engineering technology curriculum: science and mathematics; communications; humanities and social sciences; design for production; materials; manufacturing processes; manufacturing systems and automation; controls; manufacturing management, productivity and quality; computer applications; and a capstone experience. The survey instrument was printed in booklet form which arranged a series of topics under the eleven subject areas. Thirty-eight educators and 163 manufacturing managers responded for response rates of 46.9 and 32.6 per cent, respectively.



MANOVA, specifically Wilks' lambda, and ANOVA were applied to the data for each topic within the three categories of the eleven subject areas. Significance at the .05 level was found in 16 of the 33 sub-hypotheses. The groups differed significantly in respect to the importance of: humanities and social sciences; design for production; materials; manufacturing processes; manufacturing systems and automation; manufacturing management, productivity and quality; and a capstone experience. Significant differences were found in the two groups' perception of the level of instruction needed for: science and mathematics; communications; manufacturing management, productivity and quality; and the capsone experience. The two groups also differed significantly in their perceptions of the future importance of: science and mathematics; design for production; manufacturing systems and automation; manufacturing management, productivity and quality; and computer applications.

Results are compared with other studies and with recent criticisms directed toward manufacturing-related education. Recommendations for future study include replicating the study with practicing manufacturing engineers, comparing the responses according to geographic region or type of manufacturer, replicating this study in five years, and preparing a separate study to determine how much influence industrial experts have on curriculum development.



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To Dr. Manfred Swartz for his invaluable statistical assistance during the development and data analysis phases of this study.

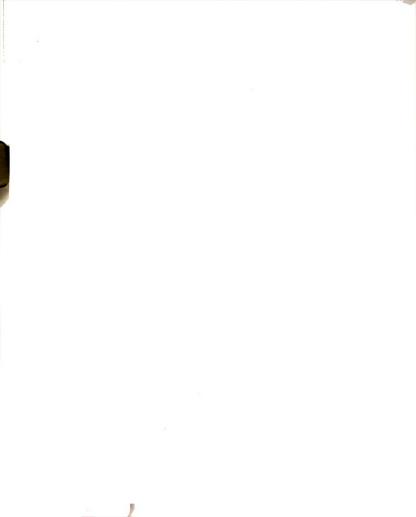
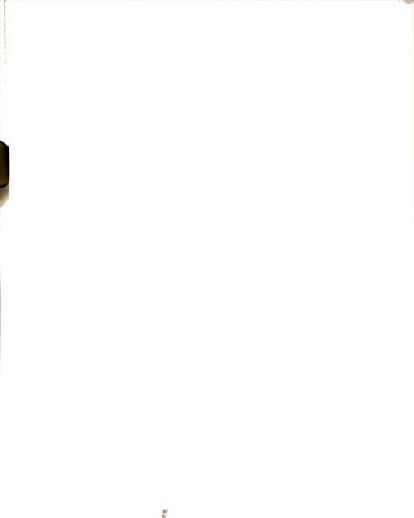


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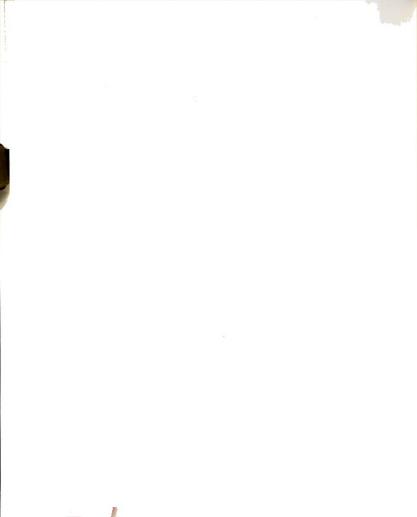
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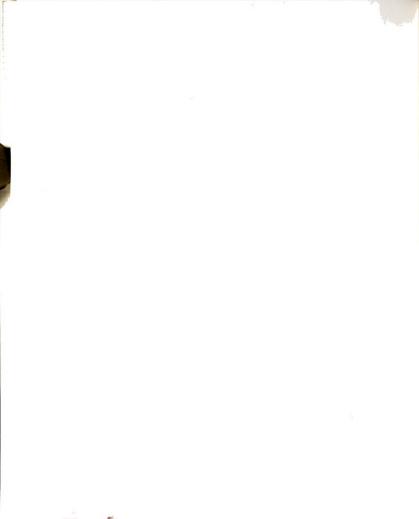
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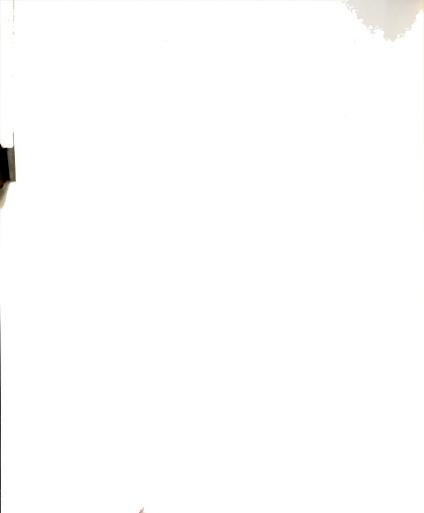


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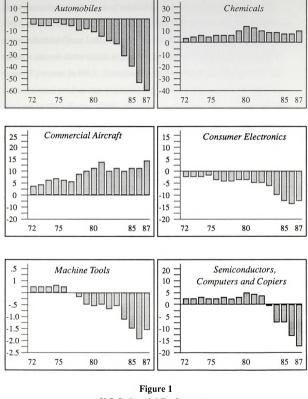
CHAPTER I INTRODUCTION

A strong relationship exists between the health of the United States domestic economy and the competitive position of United States industry in international markets. A similar relationship exists between the economic and social well-being of the United States and the performance of its manufacturing sector. Competition for manufactured goods is now clearly global and significant advances in manufacturing technology parallel the change from a domestic to a global competition.

Trends in manufacturing suggest that the United States' status in the international marketplace is steadily eroding from the dominant position it once held. A 1989 report, *Made in America: Regaining the Productive Edge* (Dertouzos, 1989), which presented the findings of a two-year study by a 16-member interdisciplinary faculty team at MIT, analyzed the U.S. industrial performance in six areas: automobiles; chemicals; commercial aircraft; consumer electronics; machine tools; semiconductors, computers, and copiers (Figure 1-1). Only chemicals and commercial aircraft have maintained a trade surplus since 1970. All other categories have experienced larger trade deficits each year. The total trade balance in manufacturing has slipped from a surplus of \$3.4 billion in 1970 to a deficit of over \$107 billion in 1985. In contrast, trade balances in Japan and West Germany over the same period have grown, respectively, from surpluses of \$12 billion to over \$107 billion and from \$13 billion to over \$59 billion (MSB/NRC, 1986).

Furthermore, manufacturing's share of the GNP has been shrinking since 1957, and since 1979 it has been shrinking fast. Official statistics





U.S. Industrial Performance

Trade surplus and deficit in six industries in billions of current U.S. dollars.



show manufacturing's share of total labor income at barely 18 per cent in 1987, down a third from 27 per cent in 1963 (TechnEcon, 1990). Even in the more industrial Great Lakes region (IL, IN, MI, MN, OH, and WI) manufacturing's income share stands at just 29 per cent, down more than a quarter from 39 per cent in 1963. Contribution by the manufacturing sector to the gross national product has decreased from 30 per cent in 1953 to about 21 per cent in 1985 (Jonas, 1986). Economists conservatively estimate that the decrease in productivity during the 1970's alone, in terms of lost competitiveness with foreign producers, caused a permanent loss of two million jobs in the smokestack industries (Magnusson, 1984).

Manufacturing is not only responsible for approximately two-thirds of the goods-producing sector of the economy (MSB/NRC, 1984); it supports employment throughout the economy. Americans "directly" employed in manufacturing number 21 million. But because of the organizational structure, the jobs of more that 50 million Americans depend directly on manufacturing production. A majority of those are conventionally counted as service workers (Jablonowski, 1987). Instead of 17 per cent of our working population being supported by manufacturing, the 50 million accounts for 42 per cent of U.S. total employment in 1988.

Every major manufacturing-related index suggests that U.S. manufacturing is not performing well and that poor performance will impact every American, not just those directly involved in manufacturing.

The inability of American manufactured goods to effectively compete in international competition has prompted intense national soul-searching. The issue has many dimensions, ranging from national monetary and fiscal



policies, to trade barriers and protection, to the management effectiveness of U.S. industry — even to the "national will" of the American people. Ultimately, however, the solution to restoring U.S. competitiveness rests with the young men and women graduating from the business, engineering, and technology programs at America's universities. They must be prepared to function effectively in a rapidly changing arena.

Nearly every diagnosis of the problems facing U.S. manufacturing eventually comes around to the issue of education. Employing new manufacturing technologies depends on the know-how of people who can use them. Responding to rapid changes in world markets requires workers who can learn new tasks and new roles quickly. The traditional manufacturing engineer needs to be equipped differently to function in this rapidly changing environment. For this reason, Emhousen (1987) suggests that technical education programs in the field of manufacturing will play a particularly significant role in restoring competitiveness to American industries.

That specialty of professional engineering known as "manufacturing engineering" focuses on the methods of production used to manufacture products and goods. Most manufacturing engineers are involved in the planning of the manufacturing process, the tooling, the machines and equipment necessary to build a product, and the integration of the facilities and the systems to produce quality products at the lowest cost.

The manufacturing engineering technologist performs the same tasks as the manufacturing engineer; however, this graduate has spent more hours in the laboratory actually designing and building products. The two disciplines are so closely related that graduates from both areas are typically hired to fill positions titled "manufacturing engineer."



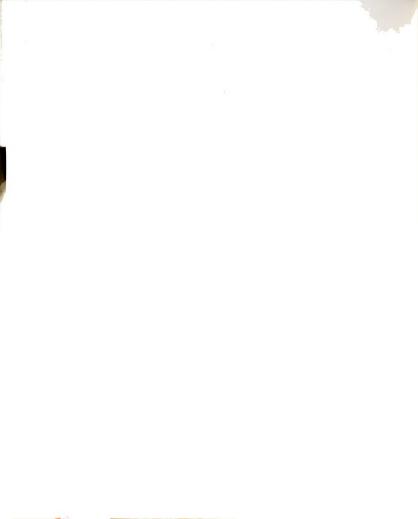
The 1986 Quality in Engineering Education Project (QEEP) study, the culmination of a two-year effort focusing primarily on professional development of faculty, but addressing key aspects of the academic working environment, commented on the relationship of engineering education and the ability of the U.S. to compete (Lear, 1990).

The drive to improve U.S. competitiveness will have a major effect on engineering education similar to that of Sputnik, which caused engineering education to place greater emphasis on engineering education. With the recent development of computer-aided analysis tools, future curriculum changes will place more emphasis on the design process and its application to the selection of the "best" option rather than detailed analysis techniques.

The process of developing and revising manufacturing engineering technology curricula at universities throughout the U.S. to respond to the national need is overwhelming. If manufacturing engineering technology faculty and manufacturing managers from industry can identify the importance of critical subject areas, establish the appropriate balance between theory and application for these subjects, and predict future subject area trends, then curriculum revision will occur rather quickly, and properly prepared graduates will be available much sooner.

Statement of the Problem

The education of manufacturing engineers and technicians must change if the U.S. is to become globally competitive. The manufacturing engineer of the twenty-first century will require a radically different



education (Riley, 1990) than universities provide today. The growth and implementation of new technologies and the dynamic changes in the management styles of manufacturing organizations will require the manufacturing engineer of the future to assume alternate roles as an operations integrator, a manufacturing strategist, and a technical specialist (Koska and Romano, 1988). This broader role is illustrated in Figure 1-2.

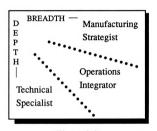


Figure 1-2
Multiple Role of the Manufacturing Engineer

For over a decade the changing role of the manufacturing engineer has been debated and discussed. Yet, few curriculum changes incorporating these broader roles have been developed, approved, or implemented (Davis and Omurtag, 1990). Recognizing the problem, the Society of Manufacturing Engineers (SME), in 1984, began surveying the manufacturing community, holding educational and industrial workshops, and conducting delphi studies. In the spring of 1990, SME published a model curriculum for both



major manufacturing-related programs, manufacturing engineering, and manufacturing engineering technology (SME, 1990a). However, neither models established the importance of the subject areas identifed, the level of instruction needed, or the future importance of the subject areas. Moreover, no single university could implement the entire curriculum model because the total recommended content exceeded the available credit hours by 50 per cent. SME recognized this problem and instructed institutions to "select one of the major categories for focused program specialization or concentration activities."

Without knowing which subject areas or categories are more important, which require additional laboratory hours, or which are declining or increasing in importance, administrators and faculty will selectively extract from the model without establishing priorities. Faculty need to understand: how important a subject area is to manufacturing managers; what level of instruction is needed to properly prepare a graduate; and what subject areas will be increasing or decreasing in importance in the future. Without such an understanding little change will really occur in manufacturing engineeringrelated curricula.

Perhaps even more importantly, individual faculty members need to sense their need to change. True educational reform usually comes down to influencing individual faculty in the classroom. Hodgkinson (1986) argues that any curriculum reform must consider how to influence the teacher in the classroom.

.... virtually nothing can influence what happens in a college or university classroom, and most people in higher education agree that it should remain that way. The notion of academic freedom is



a vital difference between K-12 education and higher education, where that notion allows the tenured college teacher to listen to no one. The college or university can best be described as a 'flat hierarchy'' in which power resides at the bottom. Faculty members can defeat any proposed action without even voting against it. They have the power to simply do nothing about reform.

Before manufacturing engineering technology faculty can revise a curriculum, they need to know what subjects are essential. Even if they are aware of the model curriculum and of the priorities within that curriculum, they may choose to "simply do nothing." However, the more they know about how their counterparts in industry perceive the appropriate curriculum, and to what extent they differ with that perception, the more likely they are to change.

Purpose of the Study

The primary purpose of this study was to determine if manufacturing engineering technology faculty and manufacturing managers differ concerning the Society of Manufacturing Engineers' recommended curriculum model for manufacturing engineering technology in respect to: the importance of subject areas, the desired level of instruction for each subject area, and the future importance of each subject area.



Research Hypotheses

Are there predictable differences in the ratings of manufacturing engineering technology faculty and the ratings of manufacturing managers in regard to recommended subject areas within the Society of Manufacturing Engineers' model manufacturing engineering technology curriculum with respect to subject area importance, the desired level of instruction, and the future importance of the subject areas? To answer these questions, the study tested the following research hypotheses:

<u>Hypothesis 1</u>. Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of *science and mathematics* within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

<u>Hypothesis 2</u>. Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of *communications* within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

<u>Hypothesis 3</u>. Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of *humanities and social sciences* within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

<u>Hypothesis 4.</u> Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of *design for production* within the recommended manufacturing engineering technology curriculum in respect to:



- a. importance
- b. desired level of instruction
- c. future importance

<u>Hypothesis 5</u>. Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of *materials* within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

<u>Hypothesis 6</u>. Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of *manufacturing processes* within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

<u>Hypothesis 7</u>. Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of *manufacturing systems and automation* within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

<u>Hypothesis 8</u>. Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of *controls* within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

<u>Hypothesis 9</u>. Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of *manufacturing management*, *productivity*, *and quality* within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance



<u>Hypothesis 10</u>. Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of *computer applications* within **the** recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

<u>Hypothesis 11</u>. Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of a *capstone experience* within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

The hypotheses were investigated using survey instruments that explored the perceptions of both groups. Limited demographic data were also collected. Survey responses were examined at the .05 level of signifiance using multivariate analysis of variance (MANOVA) and analysis of variance (ANOVA).

Delimitations

To establish clear and appropriate parameters for the study, the following delimiting factors were identified:

- The study was based on information and findings generated from educational faculty and industrial personnel in the United States. Data from foreign countries were not used.
- Only the eighty-one faculty from bachelor-level manufacturing engineering technology programs listed in the Society of Manufacturing



Engineer's "Directory of Manufacturing Education" were surveyed.

- 3. The five hundred industrial manufacturing managers selected for this study were chosen from a representative sampling of subscribers to the Society of Manufacturing Engineer's Manufacturing Engineering magazine who have identified their job junction as "Manufacturing Engineering Managers" and their primary technical interest area as "Manufacturing Management."
- 4. Due to the constantly changing nature of modern manufacturing, the identified subject areas for a model manufacturing engineering technology curriculum can only be considered useful for ten years.

Limitations

The findings of the study were limited by:

- 1. The ability to ascertain appropriate and valid data from a diverse group using a common questionnaire.
- The inability of the researcher to secure a 100 per cent questionnaire response rate.
 - 3. The time and financial restraints of the researcher.
- 4. The method used to select the manufacturing engineering technology faculty and the manufacturing managers for the study.



Definition of Terms

For the purposes of this study, terms were defined as follows:

Engineering: "The profession in which a knowledge of the mathematical and natural sciences gained by the study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials, and forces of nature for the benefit of mankind" (SME, 1990b).

Computer Integrated Manufacturing (CIM): Computer integrated manufacturing (CIM) in a manufacturing enterprise occurs when:

> -all the processing functions and related managerial functions are expressed in the form of data.

-these data are in a form that may be generated, transformed, used, moved, and stored by computer technology, and

-these data move freely between functions in the system through the life of the product, with the objective that the enterprise as a whole will have the information needed to operate at maximum effectiveness. (MSB/NRC, 1984)

"Device-Oriented": Refers to the tendency of engineers to be more enamored with "things" than with "people." This term is evident in the traditional adage "that engineers build things for people -- not with people."

Manufacturing: "A series of interrelated activities and operations involving the design, material selection, planning, production, quality assurance, management, and marketing of discrete consumer and durable goods" (Zobczak, 1984).



Manufacturing Engineering: "That speciality 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 abilility 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 expenditures" (SME, 1990b)

Manufacturing Engineering Technology: Manufacturing engineering technology is very much a part of the definition of manufacturing engineering. Technology programs normally do not require as many math and science courses as engineering programs, even though they do involve application of both. More emphasis goes into laboratory work, skill development, and applied engineering. Specifically, it is defined as, "that part of the (manufacturing) technological field which requires the application of scientific and engineering knowledge and methods combined with technical skills in support of engineering activities; it lies in the occupational spectrum between the craftsman and the engineer at the end of the spectrum closest to the engineer" (SME, 1990b).

Manufacturing Engineer: An individual who: directs and coordinates manufacturing processes in industrial plants; determines space requirements for various functions and plans or improves production methods including layout, production flow, tooling and production equipment, material fabrication, assembly methods and manpower requirements; communicates with



planning and design staffs concerning product design and tooling to assure efficient production methods; estimates production schedules; applies statistical methods to estimate future manufacturing requirements and potential; approves or arranges approval for expenditures; reports to management on manufacturing capacities, production schedules, and problems to facilitate decision-making (SME, 1990b).

Organization of the Study

The dissertation includes five chapters. Chapter I contains an introduction to the study, a statement of the problem, the purpose of the study, the research hypotheses, the delimitations and limitations of the study, and a definition of the terms used in the study.

Chapter II contains a review of the literature that focuses on manufacturing-related curricula and the growing conflict between manufacturing managers and manufacturing faculty over the substance of such manufacturing-related education.

Chapter III contains a description of the populations and samples to be surveyed, the design of the study, the survey instrument, the research hypotheses, the method of data collection and analysis, and a summary of the efforts to secure endorsement for the study.

Chapter IV contains a discussion of the findings of the study.

The summary, conclusions, and recommendations are presented in Chapter V.



CHAPTER II REVIEW OF THE LITERATURE

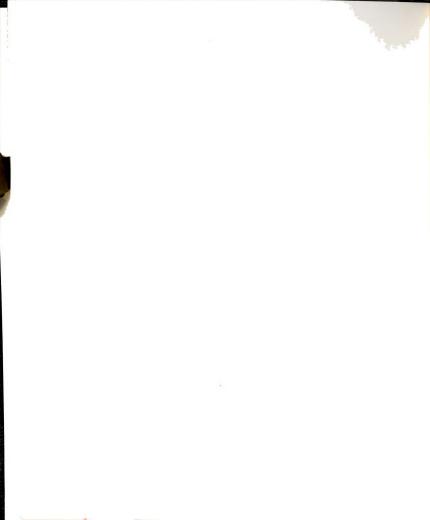
Introduction

This chapter provides an historical review of the changes which have taken place in manufacturing during the last decade, a broad sampling of recent criticisms leveled by industrial manufacturing managers and manufacturing educators at manufacturing education in the United States, and an examination of recent studies pertaining to the manufacturing curriculum.

An extensive literature review was conducted over the changing nature of manufacturing; the perceptions of U.S. manufacturing managers, executives, and educators regarding the existing manufacturing engineering curricula; and recent studies pertaining to the manufacturing engineering curricula.

The Changing World of Manufacturing

Throughout its history, the manufacturing industry has gone through successive periods of relative stability separated by periods of great change. Relative to the "good old days" of the 1950's and the 1960's, the period from the early 1970's to the present has been one of traumatic change. Wickham Skinner (1985) of the Harvard Business School claims he has never seen such a period of change in manufacturing.



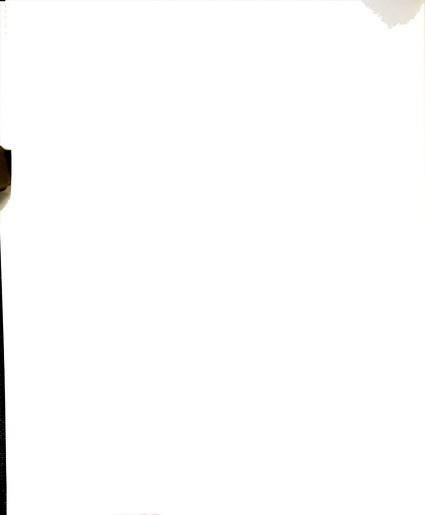
The action in manufacturing has been extraordinary in the last five years. In my own experience I have never seen such frenetic, energetic, or determined efforts. I have been writing about U.S. manufacturing since the early 1960's, but the cause of the cyclone has nothing to do with anybody's book or articles. Professors don't start revolutions. Ideas may be important, but the roots of major industrial change lie in economics and technology.

Unless domestic manufacturers recognize some of the forces causing the changes, they will undoubtedly suffer and many will fail. Some of the forces having the greatest impact on manufacturing, as identified by Gerelle and Stark (1988), include an increasing trend toward producing products for the global marketplace and the shift toward the use of computer-based information technology. Gerelle and Stark's complete list of factors causing change in manufacturing is shown in Figure 2-1.

Global Marketplace
Japanese Influence
Stagnation/Inflation
Oil Prices
Stock Market Uncertainty
Fluctuating Currency Exchange
Production Overcapacity
Environmental Issues
Electronics
Information Technology

Figure 2-1

Factors Influencing Change in Manufacturing
New materials, techniques, and technology have always been at the



root of change in manufacturing. They may be developed within a sector, result from cross-fertilization between different manufacturing sectors, or even be borrowed from non-manufacturing sectors (Gerelle and Stark, 1988). Inevitably, they revolutionize both the way products are made, as well as the actual products themselves.

The recent changes in manufacturing can be divided into four groups: structural changes, economic changes, social changes, and technological changes. The most prominent structural changes include: an expanded global market for manufactured goods, changes in international productivity levels, and the development of an international strategic manufacturing policy by most of the industrial nations in the world. When compared to other industrial nations, only Canada's productivity per unit of labor input is lower. Figure 2-2 illustrates the differences in productivity between industrial nations.

COUNTRY	Labor Productivity Growth % Output per Unit Labor Input	
	1960 - 1973	1973 - 1981
UNITED STATES	3.1	0.9
JAPAN	9.9	3.6
WEST GERMANY	5.8	3.3
FRANCE	5.9	3.4
UNITED KINGDOM	3.8	1.8
ITALY	7.8	1.4
CANADA	4.2	0.4

Figure 2-2
International Comparisons of Recent Productivity Trends
(Source: W. Fellner, ed. Essays in Contemporary Economic Problems)



The economic and financial changes such as inflation, interest rates, and currency exchange rates have had a major impact on manufacturing during the last two decades (Hayes, Wheelwright, and Clark, 1988). Such factors shortened return on investment periods and caused many manufacturing firms in the U.S. to postpone the replacement of out-dated capital equipment. Major social changes, including increased public sensitivity to environmental issues and to product quality and safety, caught many domestic manufacturers unaware.

Perhaps, the most important change during the last decade has been the influence technology has had on manufacturing. Electronics, new materials in plastics and composites, new production techniques designed around flexible manufacturing cells, and the ability to move information rapidly via technology have all changed the way products are manufactured (Cohen and Zysman, 1987). The Manufacturing Studies Board of the National Research Council (MSB/NRC, 1984) viewed the use of technology within manufacturing as the key to regaining competitiveness.

A major reason for the decline (in U.S. manufacturing competitiveness) has been the gradual emergence of a technology gap in manufacturing. The keys to regaining competitiveness in most U.S. manufacturing industries are quality, productivity, and responsiveness in bringing new products to the marketplace. A primary technology for attaining these attributes, across industries, is computer-integrated manufacturing the computer, today's prime tool for manipulating and using data, offers the very real possibility of integrating the now often fragmented operations of manufacturing into a single, smoothly operating system.



The changes in manufacturing over the last ten years, caused by the continuous advancement and implementation of computer-related automation, have been dramatic. Every business now has to master the science of manufacturing — the analysis, subdivision, and control of tightly defined conversion tasks. Otherwise, its factories will remain hopelessly unfit for world competition. Only through the use of computer information technology can the science of manufacturing be mastered.

This "integration of the computer" is commonly referred to as computer integrated manufacturing (CIM), the use of computer technology to support the integration of all functions of a manufacturing business.

Harrington (1984) argues that this technology is just what is needed in manufacturing because the discrete elements of manufacturing cannot be analyzed independently.

Manufacturing is an indivisible, monolithic activity, incredibly diverse and complex in its fine detail. The many parts are inextricably interdependent and interconnected, so that no part may be safely separated from the rest and treated in isolation, without an adverse impact on the remainder, and thus on the whole.

Harrington then suggests that because interconnectivity in manufacturing is so important, the computer is ideally suited to link the acts of manufacturing together as one continuum of data.

Every one of the acts of manufacture, and every bit of the managerial control of those acts of manufacture, can be represented by data. Data is generated, transformed and transmitted. In the ultimate analysis, all of manufacturing can be seen as a continuum of data processing. Data processing provides the one base to which all the parts may be related, the one thread that ties all the parts together.



Gunn (1986) schematically represents the CIM framework in this fashion (Figure 2-3).

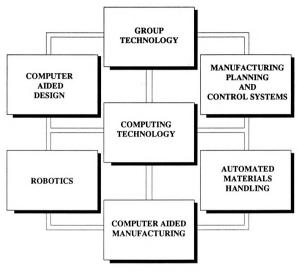


Figure 2-3
A Computer Integrated Manufacturing (CIM)Framework

The rapid introduction of computer technology represents only a portion of the change caused by the introduction of new technology into the manufacturing environment. Rigid styles of production traditionally



associated with heavy industries are being abandoned for flexible production techniques which permit industries to respond to the rapidly changing demands of consumers. These changes have virtually eliminated many tasks requiring mere physical strength. Few manufacturing tasks actually require full-time manual control by a worker anymore. As a result, the number of people employed in "direct labor" has been declining steadily since 1975. Direct labor is now such a small percentage of the total cost of production that it is considered a relatively small target for further cost savings compared to other possibilities. Today, direct labor averages less than 15 per cent of the cost of most manufactured goods; in five years that number is likely to seem as extravagant as 3 per cent defect rates did recently (Chase and Garvin, 1989).

However, the number of people employed, preparing the body of knowledge necessary for operating a manufacturing facility, has increased substantially. Such changes require that companies hire manufacturing engineers who are able to function effectively in this new and rapidly changing environment. Many smaller companies are looking to recent university graduates to assist them through this period of traumatic change.

Unfortunately, adequate numbers of university graduates with the competencies and knowledge necessary to provide such leadership are not available. Without the highly automated manufacturing labs commonly found in most of the manufacturing facilities in America, graduates remain poorly prepared to assist companies in need. Robert Anderson (1985), Manager of Technical Education at General Electric, sees the lack of technical competence in recent graduates as a serious problem.



Today's growing rate at which new technologies are being introduced into manufacturing has created a large demand for engineers competent in the new technologies. The universities, however, cannot produce new graduates in sufficient numbers or with adequate knowledge and skill to meet industry's need.

In the past manufacturing engineering education has been said to be lagging industry by as much as ten years due to the number of years required to publish a text; and due to the current knowledge of our faculty who may have been hired from industry more that ten to twenty years ago and therefore, lack knowledge of recent developments in industry (McLuckie, 1987). Today, universities may be even further behind.

As the manufacturing environment changes, so does the role of the manufacturing engineer. It's a whole new ball game in the engineering office and out on the plant floor, and it's back to the drawing board for everyone in the loop, including the educators who are trying to prepare engineers for the world of manufacturing (Stauffer, 1989).

Competitive advantage, both domestic and, more importantly, global, has heightened the resurgence of industrial interest in how universities are preparing graduates for the manufacturing fields. It is quite similar to the late 1950's after the launch of the Sputnik when universities played crucial roles in harnessing technology for national objectives (Torrero, 1984).

The debate over how graduates should be prepared to function in this constantly changing environment is often heated. None of the parties involved have escaped criticism -- educators, universities, industrial leaders, corporations, and even students. All have been blamed in part for manufacturing's demise.



The Criticisms

The difficult times encountered by large portions of base industries throughout the United States during the early 1980's sent shock waves through the manufacturing community. Engineering educators, professional societies, and corporations all were jolted into seriously examining the strengths and weaknesses of American manufacturing. The first step in the process was assessment — for education in, as well as the practice of, manufacturing (SME, 1990a). The forums varied from informal discussions to elaborate seminars and workshops; however, the outcomes were similar—the world of manufacturing had changed, and many U.S. manufacturing firms had been caught unaware.

Since the early 1960s, undergraduate engineering programs have been criticized for their inability to produce engineers who understand design and production (Evans, 1990). However, the criticism is much broader now.

Most recent criticisms can be grouped into three categories:

- the lack of an appropriate balance between theoretical and practical experiences which provide the student with an understanding of "real-world" engineering,
- the lack of an integrated educational experience which involves students in a variety of disciplines, and
- the lack of a faculty concern and understanding of the changing manufacturing world.

The lack of an appropriate balance of theoretical and practical experiences in a manufacturing engineering curriculum has been a standing argument in the engineering community for many years. The 1989 report,



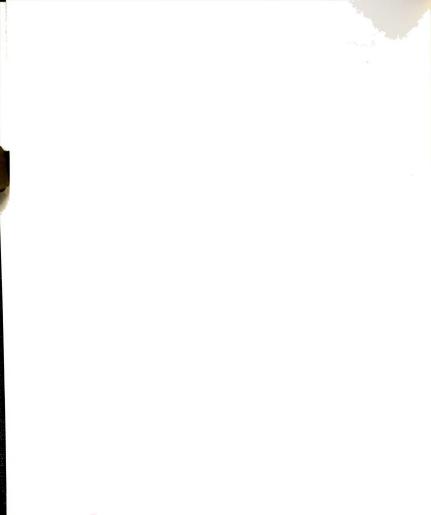
Made in America (Dertouzos, 1989), which presents the findings of a twoyear study by a 16-member interdisciplinary faculty team at MIT, addressed the issue.

The postwar evolution of the engineering curriculum in the direction of engineering science was both inevitable and desirable; theory and practice are each essential components of modern engineering education. But by now the pendulum has probably swung too far from real-world problem-solving, especially as it relates to industrial production.

Several comments from the industrial participants involved in the 1988 SME delphi manufacturing survey (Koska and Romano, 1988) seem to agree with the *Made in America* assessment.

- ... the formal education that engineers receive at our universities seems to get more theoretical and less relevant to getting a job done through and with people, every day.
- \dots transform the attainment of an undergraduate engineering degree into both a practical and theoretical experience.
- ... today, most manufacturing engineers have not achieved the proper balance of breadth and depth skills necessary for success in future decades.
- ... emphasis on reeducation has been focused solely on the expansion of depth skills. This trend must be reversed so that manufacturing engineers become better equipped to meet the challenges of the future environment.
- ... in all fairness, it is not that American college students are not learning anything, it is just not enough of the right thing.

These comments also seem to reflect the sentiments of several major manufacturing executives. Jerry Junkins (Junkins, 1989), the CEO of Texas Instruments, believes that only an adequate supply of engineers, scientists, and technically competent workers who possess a vast range of skills, which



will permit them to convert research results into products of highest quality at competitive costs, will suffice. He believes graduates understand too little of the practical side of the profession to function in the changing manufacturing world.

Product quality has become recognized as an essential element of competitiveness by industry, but today's educational curriculum still offers little exposure to practical aspects of a "quality culture."

Simon Ramo (1989), co-founder of TRW agrees with Junkins and wonders if a university education will really address the real engineering needs of industry.

American university education, especially in engineering, contrasts wildly with real-world engineering.

There has always been a tug-of-war between industry's focus on immediately applicable skills and the university's commitment to fundamental knowledge and understanding. There is some evidence that engineering education has been skewed by the pattern of Federal research funding. Critics have charged that the research culture of engineering schools emphasizes theory and research, failing to teach solutions to problems of design, production, and manufacturing with which most working engineers must deal (U.S Congress, 1988). This problem is compounded by a growing shift toward more theoretical cognitive learning experiences with less applications-oriented manufacturing engineering coursework. Decades ago, American engineering schools moved away from the curriculum of engineering practice into a curriculum of engineering

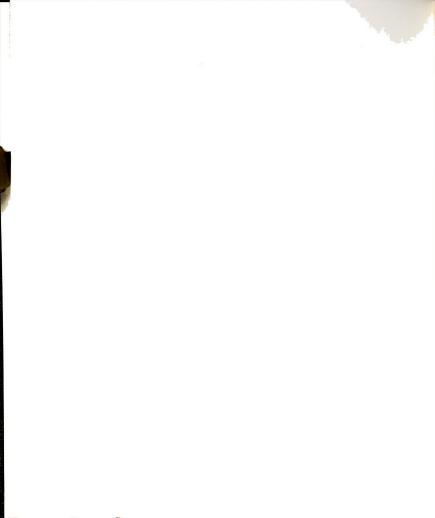
sciences. This resulted in a shortage of adequately trained manufacturing engineers (Dept of Commerce, 1990). The shift spawned the manufacturing engineering technology degree, which reduced the emphasis on the engineering sciences, while providing more engineering practice. As classical manufacturing engineering education moves deeper into science and mathematics, manufacturing engineering technology education will face increasing pressure to do the same. Troxler (1989) argues that the mathematics and science content of these programs has to be rigorous, but not so advanced and in such quantity that faculty and students will be forced out of the laboratory.

In a recent article in *Engineering Education*, Denis Lee (1989) lamented over the problem.

Clearly something is missing from our traditional engineering curriculum. There is a fundamental difference between how engineering problems are defined in the classroom versus how such problems are formulated in the real world.

Lee hesitated, however, when asked precisely how such an experience could be included. He suggested that engineering educators can accompliish the needed changes only by involving industry in the process and by making very careful decisions about curriculum content.

Decisions about these changes will have to be made defily, balancing specialization in one engineering discipline with breadth across all; tightly structured teaching with open-ended learning; practice-oriented projects with basic research; and innovative programs with concern for long-term academic development.



Many educators outside of the manufacturing discipline recognize the need for changing higher education, in general, through increased input and guidance from the industrial and business community. Such input would, from Lynton's (1983) perspective, be instrumental in enhancing the usefulness and liberalness of a graduate, thereby permitting them to lead a more productive and rewarding life.

We need nothing less than a fundamental examination of the characteristics and the requirements of professional activity, and indeed of effective human activity generally in a complex and changing society. We must learn to recognize the need for forms of understanding other than the purely cognitive, and develop from this an assessment of our educational responsibilities. We must search for a new epistemology of action more appropriate to reality than the positivism which has to date dominated all our teaching. It will be very difficult to accomplish this, and academics cannot hope to do this by themselves. We must have the courage — and the self-confidence — to take a truly revolutionary step, which is to work with prospective employers and other "outsiders" in a thorough exploration of the optimal mode of education to achieve that combination of usefulness and liberalness which really prepares and maintains an individual's ability to live a productive and rewarding life.

The field of manufacturing engineering has always required a full appreciation of the interdisciplinary nature of modern production methods. However, recent criticisms regarding the narrowly focused curricula reflect the growing perception that the role of the manufacuring engineer should be much broader. Thus, the educational curriculum should be expanded to accommodate the need.

The debate has been fueled by the understanding that in the "factory of the future," where computer technology is used to support the integration of all functions of a manufacturing business (CIM), the manufacturing



engineering will function more as an operations integrator and a manufacturing strategist, than the technical specialist's position for which most universities train them (Koska and Romano, 1988).

Many observers are calling for universities and industrial leaders to work together to develop a truly integrated curriculum.

Manufacturers and educational institutions must work together to set the standards for better educated, multidisciplined people who will understand each other's functions (Krause, 1988).

At the 1988 SME conference, "Key Strategies for Teaching Automated Manufacturing," Michael Kelly, Director of the Computer Integrated Manufacturing Exchange at the New Jersey Institute of Technology, articulated the need for increased interdisciplinary approaches to manufacturing education (Kelly, 1987).

Engineering graduates are usually able to apply their knowledge and analytical skills in solving specialized technical problems. Their education, however, has not provided them with the interdisciplinary background and systems orientation required to solve today's complex industrial problems. The typical theoretical science and mathematics-based curricula encourages the analytical approach to problem solving, while system design, integration, and syntheses are what industry needs.

Kelly proceeded to identify one of the primary reasons such a curriculum would be difficult to develop.

The continuing difficulty of faculty from disparate disciplines to collaborate on interdisciplinary research and teaching and to effectively contribute to the development of interdisciplinary curricula are major deterrents to meeting the needs of industry.



Several participants in the delphi portion of the A.T. Kearney study, commissioned by SME (Koska and Romano, 1988), called for less emphasis on the technical differences in programs.

The manufacturing engineering professional must be broader by the year 2000 if U.S. industry hopes to remain competitive. The most serious problem facing the manufacturing technical community is the overemphasis on technical differentiation.

The other side of the issue was articulated by a participant's prompt response.

The acquisition of more in-depth skills will continue to be a necessary goal for manufacturing engineers of the 21st century.

Recent studies show that over 41 per cent of the engineering schools offering a manufacturing engineering degree now offer some form of an interdisciplinary program (Taraman, 1988). However, such offerings have been severely criticized by the traditional engineering education community. Most critics of such programs argue that they are merely a smorgasbord of courses -- not a true interdisciplinary degree. Lee's (1989) opinion reflects that argument.

One pitfall to avoid in curriculum design is what I call the "Chinese-menu approach." Multidisciplinary approaches have been in vogue for some years. Unfortunately, many such proposed engineering education programs seem multidisciplinary more in name than in substance; too often these programs consist only of a consortium of courses drawn from different specialized disciplines.

The criticisms reserved for faculty affiliated with manufacturing engineering programs often come from both industrial leaders and educators.



An educator discussing the need for improved relationships between industry, government, and universities, told educators at the 1989 SME Conference, "Key Strategies for Teaching Automated Manufacturing," that they could no longer live in isolation (Ajayi-Majebvi, 1989).

Faculty at institutions of higher education have in the past safeguarded their academic freedom and integrity by isolation. The growth of the U.S. economic system and the dependencies that have been set in place, such as the need for highly skilled labor in the workforce, and the need to transfer technology chiefly by the government and universities, all combine to render such traditionally held notions as the "ivory tower" very expensive pastimes which neither the government, industry, or institutions of higher education can any longer afford.

Charles Carter (1987), Executive Director of the Institute of Advanced Manufacturing Sciences, believes that faculty will need to be moved by competition or some other external force before change will occur.

Educators have not been moved by market opportunity or by competition to make the appropriate changes. They must be so moved before significant changes can take place.

In a letter to Philip Trimble, the Executive Director and General Manager of SME, Frank Riley, Senior Vice President of Bodine Corporation, described his observations of manufacturing educators after they had listened to several industrial speakers discuss the real needs of industry (Trimble, 1990).

..... the professors who sat at the plenary session were very disturbed by the comments of the industrial speakers about the real needs of industry as they perceive them from their companies' own position and human resource needs.



A sampling of the industrial comments regarding manufacturing engineering faculty from the delphi portion of the A.T. Kearney study, commissioned by SME, seems to reflect the prevailing sentiment (Koska and Romano, 1988).

- ... university folks just won't listen.
- ... universities are staffed by philosophers not doers.
- ... this situation is particularly alarming in view of the fact that it has existed for years, has been discussed extensively by politicians and business people and is recognized by educators. Yet, alarming little real effort has been exerted to reverse the trend.

At no time in the history of manufacturing has the process of educating manufacturing engineers been the subject of such harsh criticism. The pressure to produce competent, immediately useful graduates continues to grow. Several universities have completed major curriculum revisions during the last five years to meet the challenge. Additionally, nearly every university program in the country has introduced new computer-based courses over the last decade. Unfortunately, more scientific work needs to be done analyzing the projected competencies needed by the manufacturing engineer of the future. Obviously, industrial leaders and university faculty need to increase the dialogue for the specific purpose of defining the necessary content areas in the curriculum. Several studies have been completed which attempt to analyze existing curricula and/or define the needs of the future.



Recent Studies

Some of the most significant prior research relative to this study was completed by the Society of Manufacturing Engineers. In 1984-85, during a period of extensive self-examination by many portions of the manufacturing community, SME conducted a survey to identify how manufacturing education was being taught in engineering technology programs across the nation. Existing course materials were collected and analyzed by a group of educators working with the SME. Using the instructional materials, SME convened a meeting of twenty experienced manufacturing engineering technology educators for a workshop in August 1985 to analyze and define the minimum content of manufacturing engineering technology programs (SME, 1990a). While this research was very useful, it was void of industrial guidance and merely reflected the limited focus of the twenty educators who participated. Recognizing that the results of the first study were not valid, SME initiated a second study in 1988.

The second study collected data from 30 manufacturing engineering programs and 30 manufacturing engineering technology programs regarding program orientation and program content. From this data, SME divided all program content into eight subject categories:

- 1. Design for Production
- Materials
- 3. Manufacturing Processes
- 4. Manufacturing Systems and Automation
- 5. Controls
- 6. Manufacturing Management, Productivity and Quality



7. Liberal Studies

8. Capstone Experience

Again in April 1989, SME brought together over 90 representatives from 49 different institutions to analyze the data that had been collected and to further refine the content of ideal manufacturing engineering and manufacturing engineering technology curricula. Using the eight subject categories, the educators developed a model curriculum and SME published the results in the *Curricula 2000 Workshop Proceedings* (SME, 1990a).

While both studies conducted by SME are useful, they have several flaws. Neither of the studies actively solicited industrial input -- only educators participated. Futhermore, the selection of the workshop participants and the method of selecting the participants reduced the validity of the results. The study, however, continues to stimulate debate in the academic community, and the development of eight separate subject categories has improved the process of curriculum analysis. Unfortunately, because no content areas were eliminated, the ideal curriculum developed by the participants could only be implemented in a six- or seven-year program. Thus, while manufacturing educators often use the model for reference purposes, the model would have been greatly enhanced had a level of importance been attached to the subject areas listed.

Since 1968, in an effort to better understand the changing role of the manufacturing engineer, SME has contracted with three different consulting firms to study the role of the manufacturing engineer. The first study, *The Manufacturing Engineer -- Today and Tomorrow* (1968), completed by the Arthur Little Company in 1968, helped define the role of a manufacturing



The study suggests that the manufacturing engineer of the future will be faced with new challenges in the form of: an environment exploding in scope, multiple roles, advanced tools, and a changed work emphasis. To increase the manufacturing engineer's potential for success in the future, the study recommends that the educational system be totally revamped and that major curricular changes be implemented. Some of the specific recommendations include (Koska and Romano, 1988):

^{...} Adjust the curricula of high schools and colleges to better match the skill requirements of industry, particularly breadth skills.

^{...} Transform the attainment of an undergraduate degree into both a practical and theoretical experience.



... Use industry resources to teach manufacturing issues and concepts.

The study concludes with this sober remark.

Today's manufacturing engineers are not properly equipped to close the gap by the year 2000.

McCluckie (1987) conducted a survey of 304 manufacturing education programs in the United States concerning the status of computer integrated manufacturing (CIM) education. He asked department chairmen to rank the difficulties they encountered attempting to implement a computer integrated manufacturing curriculum. Department chairs were also asked to rank a list of CIM topics, their current level of instruction (application, problem solving, theory), the amount of equipment that was available to teach each topic, and the difficulties in teaching all of the topics at the application level of instruction. A total of 132 responses were received for a 42 per cent return rate. The data obtained were grouped according to eight different program types within three major groups - engineering, engineering technology, and industrial technology. McCluckie discovered that over 78 per cent of the respondents felt that their programs were "behind industry." Less that 13 per cent considered their program "equal to industry." Furthermore, over 81 per cent felt that CIM was important enough to warrant a major change in the undergraduate manufacturing educational programs in universities and colleges in the United States. According to McCluckie's interpretation, the results indicate that a large majority of the manufacturing educational program department chairmen were willing to change their programs to accommodate the rapid



technological changes in the industry. However, McCluckie questioned the validity of the responses because of the personal biases he perceived in the responses. He noted that,

It is not uncommon for schools to continue to teach subject areas because they have the equipment necessary for instruction in that area even when they know they are sharing outdated information.

McCluckie further speculated that:

The extent of change which is needed to upgrade our educational programs is not always well-received to develop new classes requires greater effort than has been required in the past since much of the information is too new to appear in textbooks and laboratory manuals are not available Change itself is not an easy task in any organization and many people are threatened by the process. Young faculty with new ideas who see the discrepancy between what is currently taught in education to what is occurring in industry are frequently viewed as a threat to the existing curriculum and those who teach the existing classes.

The study concluded that, due to biases associated with institutional and program loyalty, the use of educational department chairs was not appropriate when developing CIM-related curricula. To overcome these biases and to upgrade the outdated manufacturing curriculum, McCluckie suggested that industrial manufacturing managers develop a list of the competencies needed by future manufacturing engineers. The list should become the basis for future curriculum development.

In 1984, Foston (1984) conducted an investigation to determine the ideal content for a manufacturing technology curriculum. Under the auspices of the Industrial Research Consultative Committee. Foston surveved 139



manufacturing professionals with knowledge of and experience in Computer-Aided Production and Control Systems (CAPACS). The survey listed suggested topic areas under one of four groups: general education, professional manufacturing education, computer "basics" education, and technical education. The respondents were then asked to indicate whether a listed topic should or should not be included in a manufacturing technology curriculum. The study provides a list of topic areas which are organized according to the percentage of respondents who believed the listed course should be included in the curriculum.

The study was limited because only manufacturing technology programs were studied, and the topics associated with that discipline are not directly transferable to other manufacturing engineering or manufacturing engineering technology programs. Moreover, the study does not address many of the broader issues identified in the extensive A.T. Kearney study (Koska and Romano) completed in 1988. The proposed general curriculum structure found in the study does suggest an excellent course flow model. Foston's study addressed only three of the four groups outlined in the study. General education topics were not studied. Futhermore, since the study was limited to professionals with experience in Computer Aided Production and Control Systems (CAPACS), the curriculum model reflects a distinct computer-oriented bias.

Barnhart (1988) completed a study in 1988 which attempted to generate a futures-oriented curriculum model related to CIM which could subsequently be used by industrial technology and engineering technology programs to facilitate curriculum revisions. Initially, Barnhart analyzed the



manufacturing curriculum offerings of 37 industrial technology and engineering technology programs in the United States. Courses were placed in generic topic areas and ranked in order of importance, as determined by the semester credit hours required in each topic area. The second phase of the study used a delphi format involving 30 computer integrated manufacturing experts selected by SME, to produce and rank 149 competencies needed by manufacturing graduates from both programs in 1993.

Even though the data generated by both studies provided meaningful information, Barnhart concluded that it was not possible to generate a curriculum model for either program area from his research because the data from the two groups studied did not directly correlate. The study did produce a list of existing manufacturing engineering subject areas, which were ranked according to credit hours required, and a separate list of ranked topic areas, which the delphi study group perceived to be important in the future. While it was virtually impossible to precisely compare the results of the two studies, Barnhart did attempt to identify those content areas where differences were clearly identifiable. The differences Barnhart noted in the responses from the two groups specifically studying manufacturing engineering technology were:

- a) The data from the analysis of degree plans ranked Metal Processing the highest, but similar competencies were rated low by the delphi panel.
- b) Topic areas in the Material Science and Mechanical areas were ranked in the upper 25 per cent of the degree plans, but were rated in the lower 25 per cent by the delphi panel.
- c) Personnel Management was ranked near the top by the delphi panel, but was ranked next to the bottom in the degree plans.



d) Computer Science and Communication skills were ranked high by the delphi panel, but were low on the degree plans.

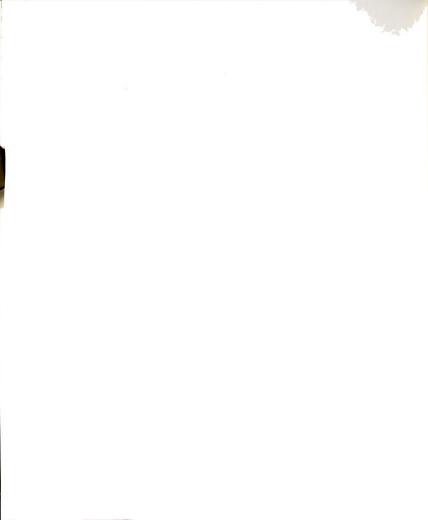
Barnhart concluded his study by recommending that future studies examine each content area more carefully. Furthermore, he recommended that future studies solicit more detailed industrial information about future competencies needed for manufacturing professionals.

Taraman (1988) studied the major characteristics of 39 universities offering undergraduate and graduate manufacturing engineering programs in the United States. A survey, sent to 57 institutions listed in the SME Directory of Manufacturing Engineering Programs, solicited from program chairs a list of program courses and unique program characteristics. Taraman received a response from 39 universities for a response rate of 68 per cent. He was able to identify 34 different graduate-level manufacturing courses offered at the 39 institutions. Ten different characteristics were identified and the percentage of institutions having those characteristics were listed.

Taraman's study is limited to graduate programs and relates strictly to manufacturing engineering. The study does include an excellent program matrix for each institution he surveyed which permits the grouping of institutions according to concentrations or program focus.

Sitkins (1986) completed a limited analysis of some of the specific requirements of manufacturing engineering technology programs and their relationship to the advancement of CIM. From the analysis, he identified seven general competencies that a graduate from a manufacturing engineering technology curriculum should possess.

- 1. Set up, operate, and compare the function of standard machine tools and processing equipment.
- 2. Design, locate, evaluate, and specify the purchase of tools, tooling, and tooling components for production systems.
- 3. Communicate effectively with production, engineering, and managerial personnel in a manufacturing environment.
- 4. Relate product design criteria to material selection, and alternative manufacturing processes.



- 5. Design and conduct tests of materials, analyze results, and appropriately relate to product and/or process requirements.
- 6. Assess machine capabilities and personnel requirements in the selection of a manufacturing system.
- 7. Specify, design, implement, and test computer software and hardware installations for monitoring and/or control of manufacturing equipment used in advanced processing systems.

He prefaced those competencies with this statement:

A command of both fundamental concepts and practical experiences in mathematics, basic and applied sciences, computer applications, and technical skills provides the foundation for dealing with rapidly changing technologies.

Unfortunately, while very useful, Sitkins study did not involve industrial practioners. Futhermore, most educators and industrial reviewers would agree with those competencies; however, each might develop a totally different curriculum to accomplish those goals.

Hull (1986) also addressed the general competencies needed by a future manufacturing engineering professional. He identified three characteristics that future manufacturing engineering professionals should have.

- 1. Understand how systems and subsystems are interrelated.
- Possess an interdisciplinary background with a broad background of skills in electrical, mechanical, fluid, thermal, optical, and microprocessing areas.
- 3. Possess a strong base of technical skills and, therefore, be capable of learning new specialties as the technology changes.



Summary

The traumatic changes in the manufacturing world over the last decade have altered the role of the manufacturing engineer. The changes are well-documented. The challenge that faces educators in manufacturing-related disciplines is how to develop the appropriate curriculum and necessary facilities for such a rapidly changing field. Due to the time lag required to implement curriculum changes in academia, long-range plans need to be established. These plans must consider what the future will require of employees in the way of competencies and educational background (Barnhart, 1988).

Developing the appropriate curriculum has been hindered by rhetorical debates over the issue. Discussions between industrial leaders and university educators pertaining to manufacturing programs are often tainted with inuendos and personal opinions. The criticisms can be grouped into three areas: the lack of an appropriate balance between the theoretical and the practical, the lack of an integrated educational experience, and the lack of concern demonstrated by faculty.

Some work has been done studying the content areas of a bachelorlevel manufacturing engineering technology curriculum; however, no studies were found that established the relative importance of subject areas, the level of instruction needed, or the topics that will be important in the future.

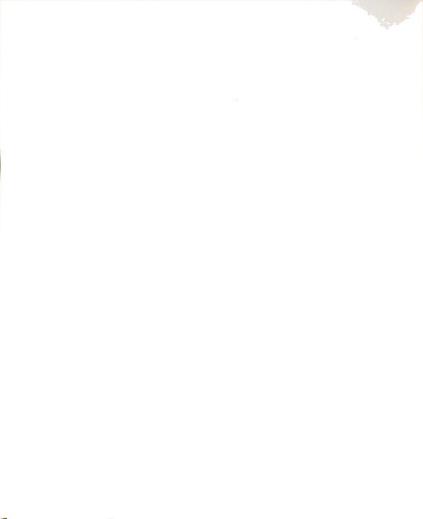
There are several themes which are prominent in the literature: manufacturing engineering curricula need revising, the manufacturing engineer of the future must be more broadly-based without sacrificing technical depth; many faculty in these disciplines lack an awareness of the existing world of manufacturing, and more research is needed which addresses the relative importance of subject areas, the perceived level of instruction needed in each subject area, and the perceived future importance of subject areas. Furthermore, manufacturers need to understand how their perceptions in each of these areas differ with those of industrial manufacturing managers.



Finally, hidden beneath the remarks of nearly every industrialist lie words of caution, "Don't be so smug -- competition may get you too."

University programs that address the need for curriculum change now will be able to expand and become more diverse in the future (Ungrodt, 1984). Those that do not may suffer the same fate as the industries that choose not to upgrade and change. Anderson (1987) puts it this way.

Like every societal institution, universities must continue to meet society's current needs or they will face the prospect of being replaced by other institutions.



CHAPTER III RESEARCH METHODOLOGY

The primary purpose of this study was to determine if manufacturing engineering technology faculty and manufacturing managers differ concerning the major categories and subject areas recommended by a Society of Manufacturing Engineers' task force for bachelor-level manufacturing engineering technology programs in respect to: 1) the importance of the subject area, 2) the desired level of instruction, and 3) the future importance of each subject area.

Populations and Samples of the Study

To determine if manufacturing managers and manufacturing engineering technology differ in respect to: 1) the importance of subject areas, 2) the desired level of instruction, and 3) the future importance of subject areas; two populations were studied: industrial manufacturing managers and bachelor-level manufacturing engineering technology faculty.

Industrial Manufacturing Managers

This population was defined as those subscribers to the Society of Manufacturing Engineers' (SME) Manufacturing Engineering magazine living in the United States who have identified their job function as "Manufacturing Engineering Management" and their technical interest area as "Manufacturing Management." This population has an understanding of the



manufacturing industry and the role of the manufacturing engineering technologist within the engineering spectrum. There are 8,512 subscribers that match this criteria.

From this population, the SME randomly generated a sample of 500 subscribers. No additional restrictions were imposed. The sample includes personnel from all types of industries, all geographic regions of the country, and from small to large companies. Two copies of the 500 mailing labels were provided to facilitate both the initial mailing and the anticipated follow-up letter.

Manufacturing Engineering Technology Faculty

This population was defined as those faculty who teach in ABET (American Board of Engineering and Technology) accredited, bachelor-level manufacturing engineering technology programs in the United States and are listed in the 1990 edition of Society of Manufacturing Engineers' "Directory of Manufacturing Education." The entire population of 81 faculty was surveyed.

Research Design

Survey research was used to collect, compare, and describe data from the two samples of two different, but interrelated, populations. According to Kidder (1981), survey research is ideally suited to study naturally occurring phenomena. The formatting of the instrument, the questioning technique, the cover letter, and the system used followed the "total design method"



recommended in Dillman's (1978) Mail and Telephone Surveys. The "5-1/2 x 8-1/2" booklet-form instrument had an informative and graphic cover designed to appeal to recipients in the manufacturing field. The back cover of the booklet reminded the participants to return the questionnaire. It also contained some graphics and a note of appreciation. Inside the booklet, the first page provided the participants with a brief and carefully worded set of instructions. Within the body of the questionnaire, the eleven categories were capitalized and set apart using a bold and italicized font. Each of the subject areas under the categories were indented and followed by a brief list of subtopics for additional clarity. Each of the pages were sequentially numbered for easy reference. The questionnaire booklet was stapled in the middle for easy opening and tighter booklet construction. Instructions for returning the completed questionnaire, along with the return address, were located in the cover letter, the questionnaire, and on the return envelope. Instructions for securing a copy of the survey results were provided in the booklet and in the cover letters.

Particular attention was paid to the style and appearance of all correspondence sent to the survey participants. Every effort was made to create a professional image in order to elicit maximum response. The official letterhead stationery and envelopes of Ferris State University were used for all correspondence. The survey instrument, the return envelope, and the mailing envelope were printed in the Ferris Printing facilities by students in the Printing Management program. Participants were told that the survey would take less than 15 minutes to complete, although respondents wishing to include narrative comments probably took longer.



Although the body of the questionnaire each population sample received was the same, the demographic questions were different. The questionnaire the industrial manufacturing managers received was printed on white paper, and the questionnaire the manufacturing engineering technology faculty received was printed on blue paper. Further, each group received a different cover letter appealing to their respective motivations for completing and returning the questionnaires. Responses were compared using statistical analysis (MANOVA) (ANOVA) techniques. All of the design elements used in the development of the survey package were intended to make response as easy as possible.

Instrumentation

To accomplish this study, a survey questionnaire was constructed to solicit information from industrial manufacturing managers (Appendix A) and manufacturing engineering technology faculty (Appendix B) regarding the importance of program subject areas, the desired level of instruction for each subject area, and the future importance of each of the subject areas. The two instruments are identical except for the demographic data requested.

After reviewing research studies with similar purposes, the researcher was not able to find an instrument appropriate for this study. Using the major categories and subject areas identified in the Society of Manufacturing Engineer's *Curricula 2000* (1990) publication, an instrument was designed to permit the respondents to rank the importance, the desired level of instruction, and the future importance of each subject area.



Cover Letter

Each questionnaire was accompanied by a cover letter which addressed the background of the study, the importance of the participant to the study, the confidentiality of the participant, the questionnaire tagging process, the usefulness of the study, the benefits (including a copy of the results) to the participant, and directions for obtaining assistance if the participant had any questions while completing the study. Each population sample, the manufacturing engineering technology faculty, and the industrial manufacturing managers, received a slightly different cover letter. The letter to the industrial managers (Appendix C) appealed to their desire to secure competent graduates. The letter to faculty (Appendix D) appealed to their desire to know which subject areas are important and what levels of instruction are needed for certain subject areas. The development of the cover letter followed the recommendations established by Dillman (1978) for effective cover letters. The cover letter to both groups also included a notice that the study was being endorsed by the Society of Manufacturing Engineers.

The cover letter was reviewed by several members of the faculty and staff at Ferris State University and by members of the Society of Manufacturing Engineers prior to mailing.

Questionnaire

The questionnaires, developed specifically for this study, to be mailed to both population samples, consisted of two major parts. The first part contained 80 subject areas divided into the eleven major categories defined

in the SME Curricula 2000 (1990) study. The second part requested demographical data from each respondent.

The cover of the questionnaire booklet described the purpose of the study, included a return address, an attractive graphical logo, several references to the study relating to "Manufacturing Engineering Technology," and notification that the study was being conducted nationwide. The back page of the questionnaire included a note of appreciation, a reminder to insert the questionnaire into the return envelope and mail it quickly, and a return address.

The first part of the body of the questionnaire included a brief description of where manufacturing engineers and the manufacturing engineering technologists fit on the occupational spectrum. The top of each page included a highlighted instruction box.

Along the left of each page, the subject areas were listed in one of the eleven major categories. Three columns with a series of numbers from one to five, on the same line as each subject area, were arranged under a description of the choices at the top of each column. Each respondent was asked to circle a number from one to five in each column. The first column related to the importance of the subject area, the second column to the level of instruction needed, and the third column to the future importance of the subject area. Above each column, the numerical choices were more clearly described. The first column, Importance of the Subject Area, included sequential choices from "Unimportant" to "Very Important." The second column, Level of Instruction Needed, included sequential choices from "Theory Only" to "Practical Only." The third column, Future Importance, included choices from "Decreasing" to "Increasing."



The second part of the questionnaire contained questions designed to collect limited demographic information about the participants using fixed alternatives. The industrial manufacturing managers were asked to identify the type of manufacturing industry in which they work, the number of employees in their company, the number of people who work under their supervison, and the nature of their formal training. The manufacturing engineering technology educators were asked if they had revised their curriculum within the last three years, how many graduates per year their program produces, what their terminal degree was, and how many industrial years of experience they had. These data were collected to permit subsequent analysis and interpretation of the responses. Other than being two different colors, this section was the only difference between the questionnaires the two groups received.

The top of the back page was used to solicit additional comments from the respondents. Most of the page was left open for comments. The bottom of the page included a note of appreciation and instructions for receiving a copy of the survey results. To maintain confidentiality, respondents interested in receiving a copy of the results were asked to write their names and addresses on the back of the return envelopes, not on the questionnaire, along with the words, "Copy of the Results Requested."



Research Hypotheses

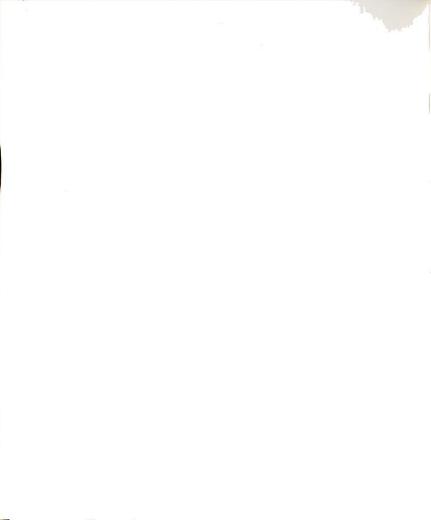
The first part of the questionnaire was composed of eleven sections covering the eleven hypotheses used in the study. The data from each group were compared for each category using three multivariate analysis of variance (MANOVA) statistical tests for importance, level of instruction needed, and future importance. MANOVA was used because it explores simultaneously the relationship between several independent variables and two or more dependent variables. It was determined that the use of analysis of variance (ANOVA) in such situations could seriously inflate Type I error rates and ignore the possibility that some composite of the variable may provide the strongest evidence of reliable group differences (Summers, 1985). An alpha level of .05 was used for all statistical tests.

Hypothesis 1. Six questions in section I were directed toward the importance, the level of instruction needed, and the future importance of *science and mathematics* subjects in the bachelor-level manufacturing engineering technology curriculum.

Hypothesis 2. Four questions in section II were directed toward the importance, the level of instruction needed, and the future importance of *communications* subjects in the bachelor-level manufacturing engineering technology curriculum.

Hypothesis 3. Four questions in section III were directed toward the importance, the level of instruction needed, and the future importance of *humanities and social sciences* subjects in the bachelor-level manufacturing engineering technology curriculum.

Hypothesis 4. Fifteen questions in section IV were directed toward



the importance, the level of instruction needed, and the future importance of *design for production* subjects in the bachelor-level manufacturing engineering technology curriculum.

Hypothesis 5. Six questions in section V were directed toward the importance, the level of instruction needed, and the future importance of *materials* subjects in the bachelor-level manufacturing engineering technology curriculum.

Hypothesis 6. Seven questions in section VI were directed toward the importance, the level of instruction needed, and the future importance of *manufacturing processing* subjects in the bachelor-level manufacturing engineering technology curriculum.

Hypothesis 7. Seventeen questions in section VII were directed toward the importance, the level of instruction needed, and the future importance of *manufacturing systems and automation* subjects in the bachelor-level manufacturing engineering technology curriculum.

Hypothesis 8. Three questions in section VIII were directed toward the importance, the level of instruction needed, and the future importance of *control* subjects in the bachelor-level manufacturing engineering technology curriculum.

Hypothesis 9. Eight questions in section IX were directed toward the importance, the level of instruction needed, and the future importance of *manufacturing management, productivity and quality* subjects in the bachelor-level manufacturing engineering technology curriculum.

Hypothesis 10. Seven questions in section X were directed toward the importance, the level of instruction needed, and the future importance of

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computer application subjects in the bachelor-level manufacturing engineering technology curriculum.

Hypothesis 11. Three questions in section XI were directed toward the importance, the level of instruction needed, and the future importance of *capstone experience* in the bachelor-level manufacturing engineering technology curriculum.

Pilot Study

Prior to conducting a formal pilot study, the questionnaire and cover letters were reviewed by the manufacturing engineering technology faculty at Ferris State University, the Director of Testing at Ferris State University, several staff members of the Society of Manufacturing Engineers, and by several manufacturing department administrators at Ferris State University. Several changes and corrections were recommended and subsequently incorporated into the questionnaire: 1) the use of letters at the top of each column to clarify the numerical ranking in each column proved to be too confusing and was replaced by the complete word, 2) the subject areas were condensed and combined to more precisely conform to the Curricula 2000 recommendations, 3) the cover of the questionnaire was rewritten twice to streamline the information, to clarify the purpose of the study, and to provide more precise instructions, 4) the differences between manufacturing engineering and manufacturing engineering technology was amplified after several reviewers indicated they were confused, and 5) the demographic data requested were revised for both groups after discussions with the staff at the Society of Manufacturing Engineers.



In accordance with the recommendations of Borg and Gall (1983), the formal pilot test was completed using the six bachelor-level manufacturing engineering faculty at Ferris State University and two local manufacturing managers. Minor modifications were made prior to printing and mailing the survey.

Data Collection

Mail surveys of the two sample groups, manufacturing engineering technology educators and manufacturing managers, were conducted. Two separate mailings were completed. The first mailing, which occurred on February 21, 1991, included the questionnaire, a cover letter addressed to each individual recipient, and a pre-printed, postage-paid return envelope. The follow-up letter was the only subsequent mailing. The follow-up letter was mailed to all participants who had not returned their questionnaires on March 13, 1991. The survey methodology deviated from Dillman's (1978) process in that a third mailing was not completed and the follow-up letter used regular first-class mail rather that the recommended certified mail.

After receiving the names and addresses from the Society of Manufacturing Engineers on February 15, 1991, initial data-entry began. Using the computer database program, Nutshell, running on a Zenith 386-SX microcomputer, three data-entry layouts and two data export layouts were designed to input and export data from a common database according to specific formats. The names and addresses of the eighty-one manufacturing engineering technology educators and the five hundred industrial manufacturing managers supplied by the Society of Manufacturing Engineers were



entered into the database. The educators were assigned the first eighty-one tag numbers, and the industrial managers were assigned tag numbers one hundred through six hundred. After all of the names and addresses were entered, the first export file was created. This file was an ASCII data file from which the Wordstar wordprocessing program sequencially extracted the needed mailing labels and individual letter saluations. Each letter was individually signed using a blue ink pen. Dillman (1978) suggests that cover letters signed with blue ink will consistently increase the response rate. The letters and mailing labels were printed on an Epson LQ-1050 programmable printer using the San Serif font set at twelve characters per inch. The cover letters were printed on Ferris State University stationery with the College of Technology letterhead. The accompanying return envelopes also included the Ferris State University logo and College of Technology, Manufacturing Engineering Technologies Department return address.

Statistical Processing

As each survey instrument was returned, the return envelopes were separated into two groups: "faculty" or "industrial." In addition, each envelope was reviewed for respondents who indicated that they would like a "Copy of the Results." Each instrument was also reviewed to determine if a respondent raised a question that merited an immediate response.

Data Entry and Layout

The responses were entered into a personal computer database program, Nutshell, which had been set up to match the layout of each naire. The database was arranged to accept only data which matched the options available to the respondent. An additional field was established for comments. Two data entry screens were prepared: one for educators and one for industrial respondents. Only the last section of the two data-entry screens differed -- demographic data. The data-entry screen initially requested the tag or questionnaire number on the instrument. Only a tag number matching one in the database which had not previously been entered would be accepted. Next, the operator was prompted to input a "Y" or "N" if the respondent had noted on the envelope that they wished to receive a copy of the results. Then the operator was prompted to enter the three circled numbers from each of the eighty questions on the questionnaire. If a number was not circled, the operator was instructed to leave that item blank. Before entering the demographic data, the operator was prompted to verify each data-entry a second time. This step reduced operator data-entry errors. Depending upon which data-entry screen the operator was in, the demographic options which appeared on the screen were selected which matched the responses on the questionnaire. After the data from each questionnaire were entered, an automatic save routine was invoked.

The second data export layout was designed to organize the data in a format which could be uploaded to the SPSS-X statistical package running on the campus mainframe, an IBM 3083 JX3. The data were arranged in six rows. The first row contained the tag number, the subsequent four rows contained eighty independent fields without separators (the numerical responses), and the last row contained the numerically sequenced responses to the demographic data. When the data collection period ended, the data export file was uploaded to the SPSS-X software system for analysis.



The responses from both groups were compared for all eleven hypotheses using the MANOVA statistical test. The data were analyzed using the SPSS-X (Statistical Package for the Social Sciences -- version 3) software package running on an IBM 3083 JX3 mainframe computer at Ferris State University. SPSS-X is an excellent software package for performing analysis of variance (ANOVA) and multivariate analysis of variance (MANOVA) statistical tests. MANOVA was used to examine the data related to all eleven hypotheses. MANOVA explores simultaneously the relationship between several independent variables and two or more dependent variables. The use of ANOVA in this study would have seriously increased the possibility of Type I errors. Furthermore, the possibility that some composite of the variable may provide the strongest evidence of reliable group differences (Summers, 1985) is ignored by ANOVA.

Endorsement

In an attempt to obtain the maximum response rate from both the manufacturing engineering technology faculty and the industrial manufacturing managers, endorsement for the study was requested and received from Ferris State University and from the Society of Manufacturing Engineers.

Ferris State University provided the letterhead stationery and envelopes, the use of the library facilities, the use of the mainframe statistical software, and also covered the mailing costs associated with both mailings (Appendix F).



The Society of Manufacturing Engineers provided the mailing list for both groups, performed the random generation of the list of industrial manufacturing managers, authorized the use of the terms "Endorsed by the SME" to appear in all references to the study, and requested a complete copy of the results of the study (Appendix E).

Summary

The study compared the perceptions of manufacturing engineering technology faculty and manufacturing managers concerning the major categories and subject areas of a bachelor-level manufacturing engineering technology program in respect to: 1) the importance of the subject area, 2) the desired level of instruction, and 3) the future importance of each subject area.

Samples from both populations were selected with the assistance of the Society of Manufacturing Engineers. A common survey instrument, apart from the demographic data requested, was used in the study for both sample populations. Respondents were asked to rank recommended subject areas according to importance, level of instruction needed for the subject areas, and future importance of the subject areas. All elements of the survey were designed using Dillman's (1978) total design method.

The first part of the questionnaire addressed the eleven hypotheses using eleven major subject categories. The second part requested additional demographic data. The final section was used for narrative comments.

The data were collected and analyzed at Ferris State University using SPSS-X software for ANOVA and MANOVA statistical tests.



CHAPTER IV ANALYSIS OF THE DATA

The primary purpose of this study was to determine if manufacturing engineering technology faculty and manufacturing managers differ concerning the Society of Manufacturing Engineers' recommended curriculum model for manufacturing engineering technology in respect to: the importance of subject areas, the desired level of instruction for each subject area, and the future importance of each subject area. Samples from both populations were surveyed with identical instruments in order to quantify any differences. The methodology used in the study was described in Chapter III.

The Sample Population

Of the eighty-one manufacturing engineering technology educators receiving questionnaires, 38 were completed and returned for a response rate of 46.9 per cent. Two respondents returned incomplete questionnaires because their respective institutions no longer offered a bachelor-level manufacturing engineering technology program. Five hundred industrial manufacturing managers were mailed questionnaires, and 163 were returned within the eight-week data collection period. The response rate for the industrial manufacturing managers was 32.6 per cent.



Research Hypotheses

Are there differences in the ratings of manufacturing engineering technology faculty and the ratings of manufacturing managers in respect to subject area importance, desired level of instruction, and future importance of the subject areas identified in the Society of Manufacturing Engineers' model manufacturing engineering technology curriculum? To answer these questions, eleven research hypotheses were tested using survey instruments that explored the perceptions of both groups.

Hypothesis 1

Industrial manufacturing managers and manufacturing technology faculty do not differ in their rating of science and mathematics within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

Hypothesis 2

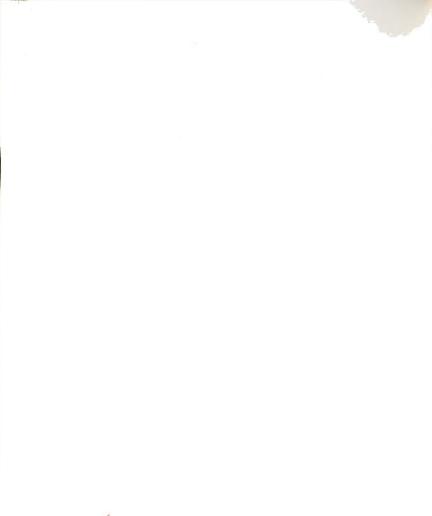
Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of communications within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

Hypothesis 3.

Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of humanities and social sciences within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance



Hypothesis 4.

Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of design for production within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

Hypothesis 5.

Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of materials within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

Hypothesis 6.

Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of manufacturing processes within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

Hypothesis 7.

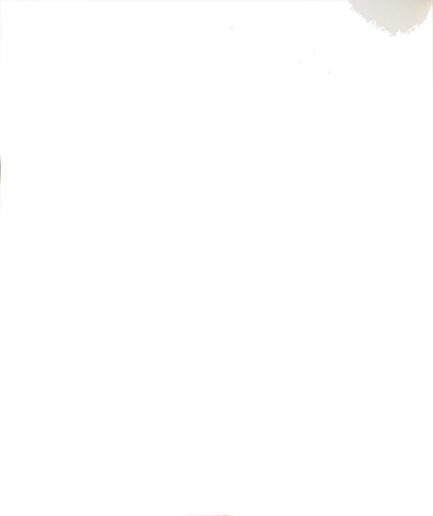
Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of manufacturing systems and automation within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

Hypothesis 8.

Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of controls within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance



Hypothesis 9.

Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of manufacturing management, productivity, and quality within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

Hypothesis 10.

Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of computer applications within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

Hypothesis 11.

Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of a capstone experience within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

Each of the eleven hypotheses were subjected to the same statistical analysis. The three categories within each hypothesis were analyzed using multivariate analysis of variance (MANOVA), specifically Wilks' lambda, to test for significance at the .05 level in any of the eleven subject area categories. If significance was found in one of the categories, the category was subjected to further analysis using univariate analysis of variance (ANOVA) to determine in which specific subject area the significance occurred. The mean of a topic was used where non-responses occurred. This permitted the multivariate analysis to include partial responses without affecting the data.



Three tables were developed for each of the eleven hypotheses.

Each table shows the multivariate analysis of the category (Wilks' lambda, the F-value, and the p-value) and the univariate analysis for each topic area within a major subject area (the mean response of each group, the standard deviation, the number of responses in each group, and the p-values for each specific subject area. Finally, the combined means from both groups for each topic within a subject area are analyzed in eleven figures.

Hypothesis Testing

Table 1 shows the Wilks' lambda, F-values, and p-values for the three categories tested within the eleven subject areas identified in each hypothesis (p = < .05 are highlighted). Figure 4.1 graphically illustrates the probability values for each category. As Table 1 and Figure 4.1 illustrate, the two groups differed in all three categories of hypothesis nine (manufacturing management, productivity and quality). However, the two groups differed in two categories over five other subject areas. In only one subject area did the two groups agree in all three categories.

Hypothesis 1

Industrial manufacturing managers and manufacturing technology faculty do not differ in their rating of science and mathematics within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

No significant difference was found between the two groups in respect to the importance of the mathematics and science subject area.



Table 1. -- Overview of the subject area and categories with significant differences between the two groups

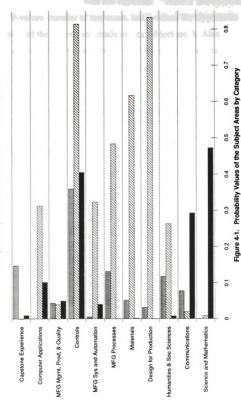
	Subject	Subject Area Importance	tance	Leve	Level of Instruction	tion	Futur	Future Importance	JCe
	Wilks'	ш	۵	Wilks'	ш	۵	Wilks'	L	۵
SUBJECT AREA	lambda			ampda			lambda		A Street
Science and Mathematics	0.97199	0.93192	.473	473 0.91618 2.95812	2.95812	*600	009* 0.89367 3.84709	3.84709	.00.
Communications	0.97522	1.24529	.293	.293 0.94229 3.00117	3.00117	.020*	020* 0.95827 2.13391	2.13391	920.
Humanities & Soc Sciences	0.93176	3.58864	.90G.	608* 0.97371 1.32314	1.32314	.263	263 0.96336	1.86381	.118
Design for Production	0.80756	2.93900	.1000.	0.95016 0.64689	0.64689	.833	0.86997	0.86997 1.84340	.032
Materials	0.89728	3.70165	.002	0.97762 0.74031	0.74031	.618	618 0.93838 2.12309	2.12309	.052
MFG Processes	0.86051	4.46940	.1000.	0001* 0.96733 0.93105	0.93105	.484	484 0.94456 1.61843	1.61843	.132
MFG Sys and Automation	0.86170	1.72768	.140.	0.90458 1.13555	1.13555	.323	323 0.83210 2.17204	2.17204	.900
Controls	0.98537	0.97513	.406	406 0.99524 0.31383	0.31383	.815	815 0.98385 1.07797	1.07797	.360
MFG Mgmt, Prod, & Quality	0.92356	1.98645	.050	0.92032 2.07782	2.07782	.040	.040* 0.92170	2.03880	.044*
Computer Applications	0.94060	1.74111	.102	102 0.95874 1.18657	1.18657	.312	.312 0.88137 3.71094	3.71094	*100.
Capstone Experience	0.94387	3.90505	.010.	010* 0.91104 6.41192	6.41192	*1000.	0001* 0.97325 1.80483	1.80483	148

*Significant at or beyond the .05 level.





Euture Importance





Therefore, hypothesis 1-A was not rejected. Table 2 shows Wilks' lambda, F-values, number of responses, and p-values for Hypothesis 1-A (importance of the science and mathematics subject area). Also shown in Table 2 are the means and standard deviations of the responses of both groups and the univariate probability for each topic area.

Table 2. -- Comparison of manufacturing managers and manufacturing educators in respect to the importance of six subject areas in science and mathematics.

MANOVA:	Wilks' lam	bda = .9719	9 F = .931	192 p = .47	3
ANOVA:	Educ	cators	Mar	nagers	
	Mean	SD	Mean	SD	р
	(n=38) (n=			=163)	
Science and Mathemat	ics				
Algebra	3.3684	0.7857	3.4596	0.6573	.459
Calculus I	3.3421	0.7807	3.0370	1.0297	.088
Calculus II	3.2973	0.8339	2.9490	0.8339	.074
Physics I	3.4211	0.6831	3.4596	0.6938	.757
Physics II	3.4211	0.6831	3.3899	0.7020	.805
Chemistry	3.2432	0.8189	3.2733	0.8011	.836

Both groups perceived the importance of all but one of the science and mathematics subject areas as "moderately important" to "important." The two calculus courses were not considered as important to the industrial manufacturing managers as they were to the manufacturing educators. To the educators, Calculus II (mean = 3.2973) was a little more important than to the managers (mean = 2.9490). The univariate analysis, however, did not reveal that there was a significant difference between the views of the two groups regarding the importance of the six subject areas listed in the science



and mathematics subject area.

The second part of the hypothesis attempted to determine if the two groups differed in respect to the desired level of instruction in the science and mathematics subject areas. The MANOVA analysis produced a Wilks' lambda of .91618, an F-value of 2.95812, and a p-value of .009 (Table 3). There was a significant difference between the two groups' perception of the level of instruction needed for science and mathematics subject areas. Thus, hypothesis 1-B was rejected.

Table 3. -- Comparison of manufacturing managers and manufacturing educators in respect to the level of instruction needed in six subject areas in science and mathematics.

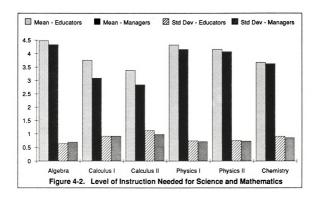
MANOVA:	Wilks' lambda = .91618 F = 2.95812 p = .009*					
ANOVA:	Educ	cators	Mar	agers		
	Mean	SD	Mean	SD	р	
	(n=	=38)	(n=	=163)		
Science and Mathema	tics					
Algebra	4.4865	0.6419	4.3333	0.6939	.216	
Calculus I	3.7568	0.9125	3.0875	0.9121	.000	
Calculus II	3.3784	1.1235	2.8398	0.9781	.003	
Physics I	4.3243	0.7372	4.1562	0.7075	.192	
Physics II	4.1622	0.7539	4.0755	0.7248	.511	
Chemistry	3.6757	0.9021	3.6211	0.8531	.726	

^{*}Significant at or beyond the .05 level.

Table 3 shows that the two groups differed significantly over the desired level of instruction needed for both calculus topics. The managers perceived that both Calculus I (mean = 3.0875) and Calculus II (mean = 2.8398) should be taught at a more "Theoretical" level than the educators



(means = 3.7568 and 3.3784, respectively). Figure 4-2 shows that both groups believed a balanced mix of theory and practice was more appropriate in calculus than in the other science and mathematics topics. However, the mean of the responses from the managers suggests that they would prefer less practical work. The larger standard deviation found in the responses to calculus from both groups indicates that there may be a wider range of views regarding these topics.



The third part of the hypothesis attempted to determine if the two groups differed in respect to the future importance of science and mathematics in the manufacturing engineering technology curriculum. The MANOVA analysis produced a Wilk's lambda of .89367, an F-value of 3.84709, and a p-value of .001 (Table 4). There was a significant difference between the



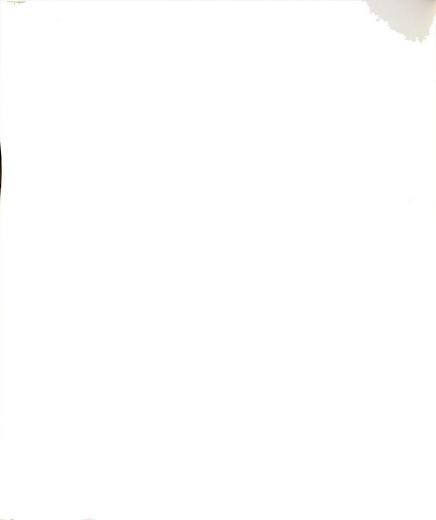
two groups' perception of the future importance of science and mathematics subject areas. Thus, hypothesis 1-C was rejected.

Table 4. -- Comparison of manufacturing managers and manufacturing educators in respect to the future importance of six subject areas in science and mathematics.

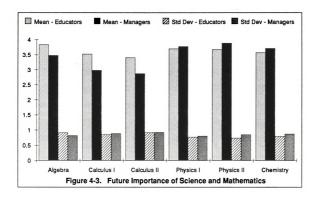
MANOVA:	Wilks' lambda = .89367 F = 3.84709 p = .001*					
ANOVA:	Educ	ators	Mar	agers		
	Mean	SD	Mean	SD	р	
	(n=	=38)	(n=	=163)		
Science and Mathemat	tics					
Algebra	3.8378	0.9157	3.4780	0.8153	.018	
Calculus I	3.5278	0.8538	2.9810	0.8852	.001	
Calculus II	3.4054	0.9141	2.8710	0.9210	.001	
Physics I	3.7027	0.7663	3.7736	0.8007	.621	
Physics II	3.6757	0.7372	3.8861	0.8460	.159	
Chemistry	3.5676	0.7898	3.7107	0.8703	.354	

^{*}Significant at or beyond the .05 level.

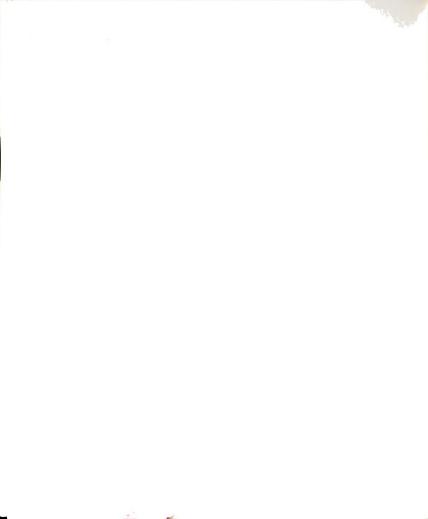
The ANOVA analysis of each topic area in hypothesis 1-C (Table 4) indicates that the managers did not perceive the future importance of the three math topics increasing as significantly as did the educators. The managers viewed the future importance of Calculus I (mean = 2.9810) and Calculus II (mean = 2.8710) just "About the Same." Educators viewed the future importance of these courses as increasing some. Even though the mean of the managers' responses (3.4780) indicates that they perceived the future importance of Algebra to be toward "Some Increase," the mean of the



educators' responses (3.8378) was significantly higher, suggesting that they viewed the future importance of those topics as increasing. Figure 4-3 illustrates that the managers perceived the future importance of physics and chemistry increasing slightly more than the educators.



Summary of Hypothesis 1. There was no significant difference between the two groups in respect to the importance of science and mathematics in the manufacturing engineering technology curriculum. However, the groups differed significantly over the level of instruction needed and the future importance of science and mathematics subjects within the manufacturing engineering technology curriculum. Manufacturing managers thought that calculus courses should be more equally balanced (theory vs. practice) than manufacturing educators, and manufacturing managers did not view



mathematics increasing in importance in the future as much as did educators. Hypotheses 1-B and 1-C were rejected. Hypothesis 1-A was not rejected.

Hypothesis 2

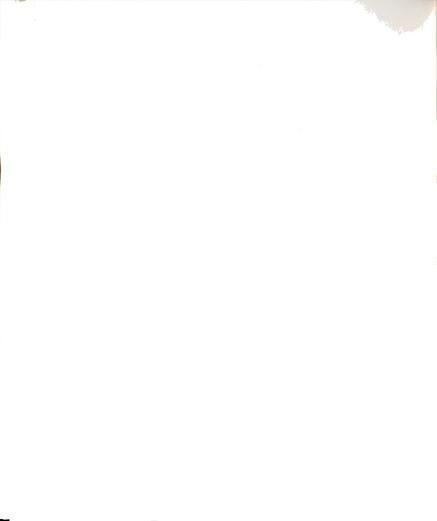
Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of *communications* within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

No significant difference was found between the two groups in respect to the importance of communications in the manufacturing engineering technology curriculum. Therefore, hypothesis 2-A was not rejected. Table 5 shows the results of the MANOVA test of significance regarding hypothesis 2-A and the ANOVA analysis of each topic area.

Table 5. -- Comparison of manufacturing managers and manufacturing educators in respect to the importance of four subject areas in communications.

MANOVA:	Wilks' lambda = .97522 F = 1.24529 p = .293				
ANOVA:	Educ	ators	Mar	nagers	
	Mean	SD	Mean	SD	р
	(n=	=38)	(n=	=163)	
Communications					
Public Speaking	3.5263	0.7255	3.7654	0.7821	.087
Tech Presentations	3.7895	0.7036	3.7728	0.7370	.929
Technical Reports	3.7368	0.7235	3.6894	0.7221	.716
Interpersonal	3.8421	0.8229	3.7950	0.7787	.740



A Wilks' lambda of .97522, an F-value of 1.24529, and a p-value of .293 indicate that the groups did not differ significantly. The managers perceived that public speaking was somewhat more important than did the educators.

The second part of the hypothesis attempted to determine if the two groups differed in respect to the desired level of instruction needed in communications. The MANOVA analysis produced a Wilks' lambda of .94229, an F-value of 3.00117, and a p-value of .020 (Table 6). As the MANOVA test revealed, there was a significant difference between the two groups' perception of the level of instruction needed in communications. Thus, hypothesis 2-B was rejected.

Table 6. -- Comparison of manufacturing managers and manufacturing educators in respect to the level of instruction needed in four subject areas in communications.

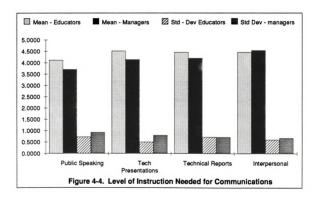
MANOVA:	Wilks' lam	bda = .9422	9 F = 3.0	0117 p=.0	117 p = .020*			
ANOVA:	Educ	ators	Mar	agers				
	Mean	SD	Mean	SD	р			
	(n=38) (n=163)							
Communications								
Public Speaking	4.1081	0.7272	3.7019	0.9219	.012			
Tech Presentations	4.5135	0.4993	4.1367	0.7973	.006			
Technical Reports	4.4595	0.7202	4.2000	0.7097	.044			
Interpersonal	4.4595	0.5970	4.5404	0.6666	.493			

^{*}Significant at or beyond the .05 level.

Table 6 shows that the two groups differed significantly over the desired level of instruction needed for three topic areas: public speaking,



technical presentations, and technical reports. Figure 4-4 graphically illustrates the differences in the means of the two groups and the standard deviations associated with those responses. Both groups perceived the level of instruction needed to be more practical than theoretical; however, educators were more consistent with their responses. The two groups did not differ significantly in respect to the level of instruction needed to develop interpersonal skills. They both perceived that this skill should be developed primarily through practical application.



The third part of the hypothesis attempted to determine if the two groups differed in respect to the future importance of communications in the manufacturing engineering technology curriculum. The results of the MA-NOVA analysis, showing Wilks' lambda, the F-value, and the p-value of the test for hypothesis 2-C, are shown in Table 7.

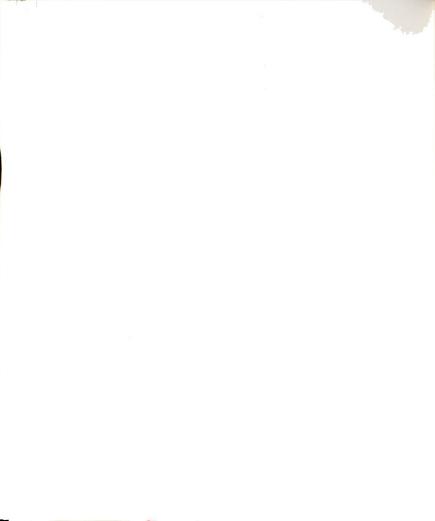


Table 7. -- Comparison of manufacturing managers and manufacturing educators in respect to the future importance of four subject areas in communications

MANOVA:	Wilks' lambda = .95827		7 F = 2.1	F = 2.13391 p =		
ANOVA:	Educators		Man	agers		
	Mean	SD	Mean	SD	р	
	(n=38)		(n=163)			
Communications						
Public Speaking	3.8889	0.8630	3.9231	0.8280	.820	
Tech Presentations	4.2222	0.8418	4.1529	0.7549	.619	
Technical Reports	4.0833	0.8815	4.0828	0.8312	.997	
Interpersonal	4.3143	0.8628	4.5669	0.6505	.045	

The two groups did not differ significantly regarding the future importance of communications in the manufacturing engineering technology curriculum. Thus, hypothesis 2-C was not rejected. ANOVA revealed that the two groups only differed over the future importance of interpersonal skills. The managers (mean = 4.5669) believed that this skill would be of more value than their educational counterparts (mean = 4.3143).

Summary of Hypothesis 2. There was no significant difference between the two groups in respect to the importance or future importance of communications in the manufacturing engineering technology curriculum. However, the groups differed significantly over the level of instruction needed for communications subjects within the manufacturing engineering technology curriculum. Manufacturing managers thought that public



speaking, technical presentation, and technical report courses should be more equally balanced (theory vs. practice) than did manufacturing educators.

Managers perceived that future interpersonal skills would be more important than did educators. Hypotheses 1-B was rejected. Hypothesis 1-A and 1-C were not rejected.

Hypothesis 3

Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of humanities and social sciences within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

The first part of the hypothesis attempted to determine if the two groups differed in respect to the importance of humanities and social sciences in the manufacturing engineering technology curriculum. The MA-NOVA test of significance produced a Wilks' lambda of .93176, an F-value of 3.58864, and a p-value of .008 (Table 8). Thus, there was a significant difference between the two groups in respect to the importance of humanities and social sciences in the manufacturing engineering technology curriculum. Hypothesis 3-A was rejected.

The ANOVA test revealed a significant difference in the two groups' perception of the importance of global awareness. The mean of the educators' responses (3.8424) was closer to "Important" while the mean of the managers' responses was closer to "Moderately Important."

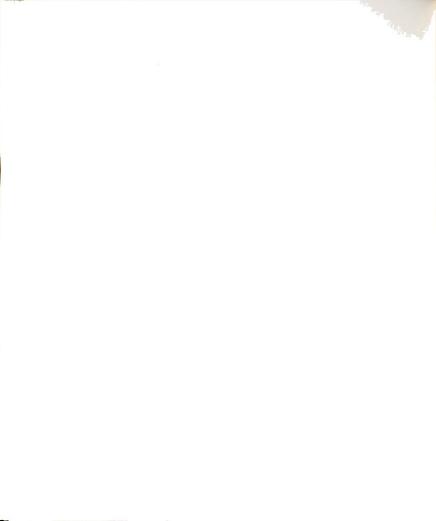
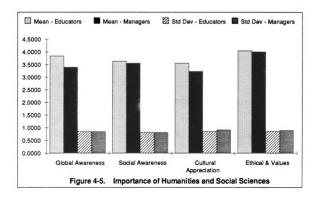


Table 8. -- Comparison of manufacturing managers and manufacturing educators in respect to the importance of four subject areas in humanities and social sciences.

MANOVA:	Wilks' lambda = .93176		6 F = 3.5	F = 3.58864 p = .00		
ANOVA:	Educators		Mar	nagers	***************************************	
	Mean	SD	Mean	SD	р	
	(n=38) (n=163)					
lumanities and Social S	ciences					
Global Awareness	3.8424	0.8551	3.3975	0.8482	.004	
Social Awareness	3.6316	0.8194	3.5556	0.8089	.603	
Cultural Appreciation	3.5556	0.8525	3.2360	0.9197	.052	
Ethical & Values	4.0526	0.8683	4.0062	0.8992	.774	

^{*}Significant at or beyond the .05 level.

Figure 4-5 graphically illustrates that the educators perceived all topics to be more important than their industrial counterparts.





The second part of the hypothesis was developed to determine whether the two groups held similar views about the level of instruction needed in humanities and social sciences. The MANOVA test of significance for this hypothesis is shown in Table 9.

Table 9. -- Comparison of manufacturing managers and manufacturing educators in respect to the level of instruction neededed in four subject areas in humanities and social sciences.

MANOVA:	Wilks' lam	bda = .9737	71 F = 1.3	2314 p=.2	:63	
ANOVA:	Educators		Mar			
	Mean	SD	Mean	SD	р	
	(n=	=38)	(n=	(n=163)		
Humanities and Social S	ciences					
Global Awareness	3.2162	0.8099	3.0750	0.8206	.339	
Social Awareness	3.1622	0.7539	3.1824	0.7015	.875	
Cultural Appreciation	3.1667	0.7884	3.1125	0.7200	.682	
Ethical & Values	3.1622	0.6373	3.2981	0.7014	.275	

The two groups did not differ significantly regarding the desired level of instruction for humanities and social science subjects. Thus, Hypothesis 3-B was not rejected. The ANOVA analysis of the topic areas did not find a significant difference between the two groups regarding the desired level of instruction in the topics identified.

The third part of the hypothesis attempted to determine if the two groups differed over the future importance of humanities and social science subjects. The MANOVA test of significance (Table 10) produced a probability of .118. Thus, the two groups held similar views about the future importance of humanities and social science subjects. Hypothesis 3-C was

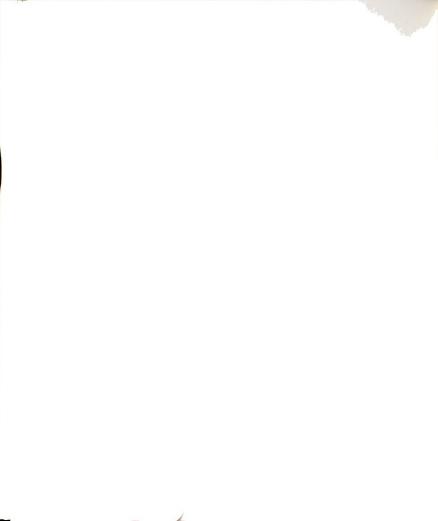


not rejected. Table 10 does reveal that the two groups differed over the future importance of social awareness. Social awareness was perceived to be more important to future manufacturing engineering technology graduates by managers (mean = 3.8875) than by educators (mean = 3.5406).

Table 10. -- Comparison of manufacturing managers and manufacturing educators in respect to the future importance of four subject areas in humanities and social sciences.

MANOVA:	Wilks' lam	bda = .963	36 F = 1.8	F = 1.86381 p = .118		
ANOVA:	Edu	Educators		Managers		
	Mean	SD	Mean	SD	р	
	(n=38) (n=163)					
Humanities and Social S	ciences					
Global Awareness	3.9730	0.9722	4.0062	0.8277	.829	
Social Awareness	3.5406	0.8572	3.8875	0.8239	.021	
Cultural Appreciation	3.4440	0.9137	3.6000	0.8255	.307	
Ethical & Values	3.8378	0.8857	4.0745	0.8356	.122	

Summary of Hypothesis 3. The two groups held similar views regarding the level of instruction desired and the future importance of humanities and social science subjects within the manufacturing engineering technology curriculum. However, they differed over the importance of humanities and social science subjects in the curriculum. Educators thought that global awareness was more important than managers, and managers thought that social awareness would be more important in the future. Hypothesis 3-A was rejected, and hypotheses 3-B and 3-C were not rejected.



Hypothesis 4

Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of design for production within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

The first part of the hypothesis attempted to determine if the two groups held similar views about the importance of design for production in the manufacturing engineering technology curriculum. MANOVA was used as a test of significance for the fifteen topics related to this hypothesis. A Wilks' lambda value of .80756 produced an F-value of 2.93900 and a probability of .0001 (Table 11). Thus, there was a significant difference between the two groups over their perception of the importance of design for production in the manufacturing engineering technology curriculum. Hypothesis 4-A was rejected.

The ANOVA test of significance identified several topics in which the two groups differed significantly (Table 11). Figure 4-6 graphically illustrates where the two groups differed the most. Manufacturing managers consistently rated these topics higher than did the educators: descriptive geometry (4.1296 vs. 3.5263), geometric dimensioning and tolerancing (4.4224 vs. 4.1316), product design (4.3043 vs. 3.7895), finite element modeling and finite element analysis (FEM/FEA) (3.3062 vs. 2.8158), design of machine elements (3.9080 vs. 3.5675), and manufacturing tooling design (4.2733 vs. 3.9737). As Figure 4-6 shows, most of the topics in this subject category were rated higher in importance by the manufacturing managers than they were by the educators. The topics rated higher by educators were also

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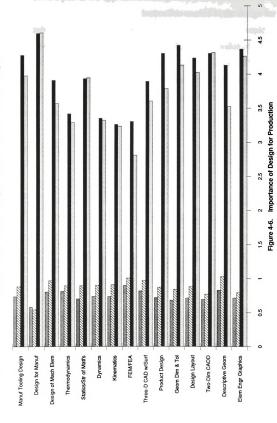
ranked very high by the managers. Furthermore, the larger standard deviations in all but one category of the educators' responses suggest that the educators were not as unified in their ratings of the topics.

Table 11. -- Comparison of manufacturing managers and manufacturing educators in respect to the importance of fifteen subject areas in design for production.

MANOVA:	Wilks' lami	oda = .8075	6 F = 2.93	900 p=.0	0001*
ANOVA:	Educ	ators	Man	agers	
	Mean	SD	Mean	SD	р
	(n=	38)	(n=	:163)	
Design for Production					
Elem Engr Graphics	4.2632	.7947	4.3665	.7174	.435
Descriptive Geom	3.5263	1.0329	4.1296	.8325	.000
Two-Dim CADD	4.3158	.7748	4.3025	.6947	.917
Design Layout	4.0263	.8849	4.2346	.7162	.125
Geom Dim & Tol	4.1316	.8438	4.4224	.6817	.025
Product Design	3.7895	.8748	4.3043	.7205	.000
Three-D CAD w/Surf	3.6053	.9737	3.8944	.8210	.061
FEM/FEA	2.8158	1.0096	3.3062	.9026	.004
Kinematics	3.2368	.9134	3.2638	.7356	.846
Dynamics	3.3243	.9021	3.3519	.7410	.844
Statics/Str of Matl's	3.9474	.8989	3.9325	.7039	.912
Thermodynamics	3.2895	.8977	3.4172	.8151	.395
Design of Mach Elem	3.5676	.9737	3.9080	.8074	.026
Design for Manuf	4.6053	.5472	4.5951	.5841	.922
Manuf Tooling Design	3.9737	.8849	4.2733	.7369	.031

^{*}Significant at or beyond the .05 level.

🖾 Mean - Educators 🔳 Mean - Managers 🔯 Std Dev - Educators 🔯 Std Dev - managers





The second part of the hypothesis attempted to determine if the two groups differed in respect to the level of instruction needed in the design for production subject area. MANOVA was used to analyze the fifteen topic areas within this subject area and category. A Wilks' lambda value of .95016 yielded an F-value of .64689 and a probability of .833 (Table 12). Therefore, there was no significant difference in the views of both groups in respect to the level of instruction needed for design for production topics. Hypothesis 4-B was not rejected.

Table 12. -- Comparison of manufacturing managers and manufacturing educators in respect to the level of instruction needed in fifteen subject areas in design for production.

MANOVA:	Wilks' lam	bda = .9501	6 F = .646	89 p=.83	3
ANOVA:	Educ	cators	Mar	agers	
	Mean	SD	Mean	SD	р
	(n=	=38)	(n=	=163)	
Design for Production					
Elem Engr Graphics	3.4054	0.6762	3.4534	0.7282	.711
Descriptive Geom	3.2973	0.7663	3.3727	0.7603	.583
Two-Dim CADD	3.5000	0.6877	3.6770	0.6992	.160
Design Layout	3.5789	0.6831	3.6358	0.6917	.648
Geom Dim & Tol	3.3684	0.7857	3.5280	0.7622	.249
Product Design	3.3243	0.6996	3.5217	0.7035	.120
Three-D CAD w/Surf	3.2368	0.6339	3.4438	0.7597	.121
FEM/FEA	2.9737	0.8538	3.1438	0.9016	.292
Kinematics	3.1316	0.7415	3.0675	0.6679	.603
Dynamics	3.1316	0.7771	3.1296	0.6951	.988
Statics/Str of Matl's	3.3684	0.7857	3.3926	0.6798	.848
Thermodynamics	3.2368	0.7862	3.1963	0.7274	.761
Design of Mach Elem	3.3513	0.7431	3.4233	0.6749	.562
Design for Manuf	3.4324	0.6384	3.6810	0.7261	.054
Manuf Tooling Design	3.4324	0.7181	3.6812	0.7317	.060



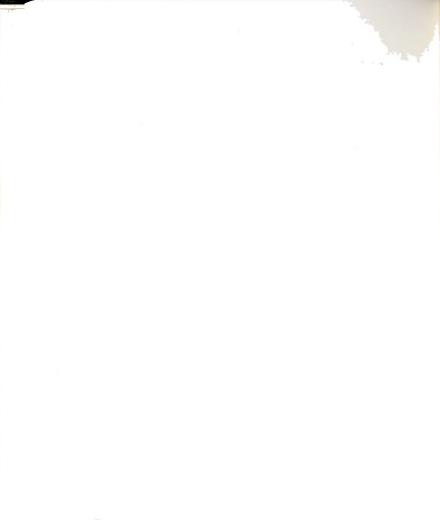
The ANOVA analysis did not reveal a significant difference between the groups over the level of instruction needed for any of the topics identified in the design for production subject area.

The third part of the hypothesis attempted to determine whether the two groups held similar views about the future importance of the design for production subject area within the manufacturing engineering technology curriculum. MANOVA was used to examine the fifteen topic areas related to this hypothesis. A Wilks' lambda value of .86997 produced an F-value of 1.84340 and a probability of .032 (Table 13).

Table 13. -- Comparison of manufacturing managers and manufacturing educators in respect to the future importance of fifteen subject areas in design for production.

MANOVA:	Wilks' lam	bda = .869	97 F = 1.8	14340 p =	.032*
ANOVA:	Educ	Educators		agers	
	Mean	SD	Mean	SD	р
	(n=	=38)	(n=	=163)	
Design for Production					
Elem Engr Graphics	3.0811	0.7490	3.5346	0.7918	.002
Descriptive Geom	2.8919	0.9237	3.5125	0.8239	.000
Two-Dim CADD	3.7632	1.0510	4.1132	0.8313	.028
Design Layout	3.5526	0.8285	3.7875	0.8042	.109
Geom Dim & Tol	3.9211	0.8505	4.1761	0.7820	.077
Product Design	3.5946	0.5909	3.9811	0.8125	.006
Three-D CAD w/Surf	4.0789	0.9118	4.1321	0.7380	.703
FEM/FEA	3.4595	0.8572	3.7342	0.8196	.067
Kinematics	3.0789	0.7491	3.2721	0.6251	.100
Dynamics	3.1316	0.7415	3.3503	0.6466	.069
Statics/Str of Matl's	3.4474	0.7952	3.6646	0.7253	.104
Thermodynamics	3.1053	0.7637	3.3291	0.7066	.085
Design of Mach Elem	3.1944	0.6905	3.5760	0.8410	.010
Design for Manuf	4.3421	0.6271	4.5975	0.6198	.024
Manuf Tooling Design	3.5263	0.8297	3.9363	0.7752	.004

^{*}Significant at or beyond the .05 level.

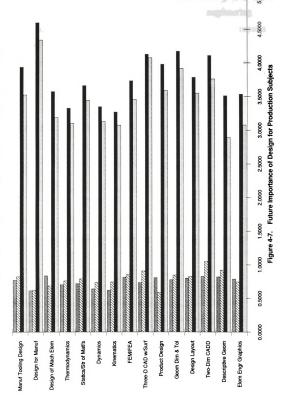


Thus, there was a significant difference between the two groups' perspective about the future importance of the fifteen topic areas identified as part of the design for production subject area. Hypothesis 4-C was rejected. The ANOVA analysis revealed a significant difference in several topics. The managers rated the future importance of all seven topics, which were tested as significantly different, higher than their counterparts in education. The differences were more noticeable in these topic areas: elementary engineering graphics (3.5346 vs. 3.0811 with p = .002), descriptive geometry (3.5125 vs. 2.8919 with a p < .000), product design (3.9811 vs. 3.5946 with)p = .006), design of machine elements (3.5760 vs. 3.1944 with p = .010). and manufacturing tooling design (3.9363 vs. 3.5263 with p = .004). Furthermore, significant differences were found in two-dimensional CADD (p = .028) and design for manufacturability (p = .024). Similar differences were found between the two groups regarding the importance of these topics in hypothesis 4-A. Apparently, educators did not perceive these topic areas to be as important as manufacturing managers, nor did they perceive them to be increasing in importance in the future to the degree that manufacturing managers suggest.

Figure 4-7 graphically illustrates that the managers perceived every topic area in this category as more important in the future than their educational counterparts. Furthermore, the larger standard deviations in the educator responses in nearly every topic area reveal a lack of unity among the educators regarding the topics. Interestingly, both groups perceived every topic area listed to either be remaining about the same or increasing some. None were identified as decreasing.



Mean - Educators
Managers
Std Dev - Educators
Std Dev - Managers





Summary of Hypothesis 4. The two groups held similar views about the level of instruction needed for the topic areas identified as part of the design for production subject area within the manufacturing engineering technology curriculum. However, they differed significantly over the importance and the future importance of design for production in the curriculum. Managers perceived several of the topic areas as more important today and increasingly more important in the future than did educators. Hypotheses 4-A and 4-C were rejected and hypothesis 4-B was not rejected.

Hypothesis 5

Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of *materials* within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

The first part of the hypothesis attempted to determine if the two groups differed in respect to the importance of the materials subject area in the manufacturing engineering technology curriculum. MANOVA was used as a test of significance for the six topic areas related to this hypothesis. A Wilks' lambda of .89728 produced an F-value of 3.70165 and a probability of .002 (Table 14). Thus, there was a significant difference between the two groups in respect to their perception of the importance of materials in the manufacturing engineering technology curriculum. Hypothesis 5-A was rejected.

The ANOVA test of significance identified only one topic area in which the two groups differed. The educators rated the introduction to



engineering materials (4.3058) significantly higher than did the manufacturing managers (3.9632).

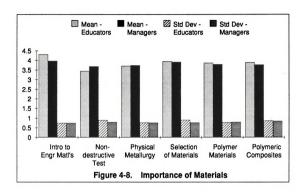
Table 14. -- Comparison of manufacturing managers and manufacturing educators in respect to the importance of six subject areas in materials.

MANOVA:	Wilks' lam	bda = .8972	28 F = 3.70	165 p=.0	02*
ANOVA:	Educators		Mar	agers	
	Mean	SD	Mean	SD	р
	(n=	=38)	(n=	=163)	
Materials					
Intro to Engr Matl's	4.3058	0.7391	3.9632	0.7444	.009
Non-destructive Test	3.4474	0.8913	3.6871	0.7898	.102
Physical Metallurgy	3.7105	0.7679	3.7391	0.7579	.835
Selection of Materials	3.9474	0.8989	3.9136	0.7649	.813
Polymer Materials	3.8684	0.7771	3.7901	0.7891	.581
Polymeric Composites	3.8947	0.8634	3.7640	0.8427	.392

^{*}Significant at or beyond the .05 level.

As Figure 4-8 illustrates, the two groups perceived the importance of the topic areas very similarly. With the exception of introductory engineering materials, the means and standard deviations of both groups in the other five topic areas are quite close. All were viewed between "Moderately Important" and "Important."





The second part of the hypothesis attempted to determine if the two groups differed in respect to the level of instruction needed in materials within the manufacturing engineering technology curriculum. MANOVA was used to analyze the six topic areas within this subject area and category. A Wilks' lambda value of .97762 yielded an F-value of .74031 and a probability of .618 (Table 15). Thus, there was no significant difference between educators and manufacturing managers in respect to the level of instruction needed in materials within the manufacturing engineering technology curriculum. Hypothesis 5-B was not rejected.

As Table 15 shows, the ANOVA test did not reveal a significant difference between the two groups over any of the topic areas. The means from both groups are close and the standard deviations are consistent.



Both groups perceived the level of instruction needed in this subject area to be a balance of theory and practice.

Table 15. -- Comparison of manufacturing managers and manufacturing educators in respect to the level of instruction needed in six subject areas in materials.

MANOVA:	Wilks' lam	bda = .9776	2 F = .74	031 p = .61	18
ANOVA:	Educators		Mar	agers	
	Mean	SD	Mean	SD	р
	(n=38)		(n=		
Materials .					
Intro to Engr Matl's	3.2632	0.7947	3.2638	0.7012	.996
Non-destructive Test	3.2368	0.7862	3.3558	0.7910	.404
Physical Metallurgy	3.1892	0.7292	3.2750	0.7366	.518
Selection of Materials	3.2432	0.8512	3.3889	0.6872	.263
Polymer Materials	3.2973	0.7663	3.2857	0.7322	.931
Polymeric Composites	3.2162	0.9045	3.2688	0.7991	.722

The third part of the analysis attempted to determine whether the two groups held similar views about the future importance of materials in the manufacturing engineering technology curriculum. MANOVA was used to examine the six topic areas related to this hypothesis. A Wilks' lambda value of .93838 yielded an F-value of 2.12309 and a probability of .052 (Table 16). Therefore, there was no significant difference in the views of both groups in respect to the future importance of materials within the manufacturing engineering technology curriculum. Hypothesis 5-C was not rejected.

As Table 16 shows, the ANOVA analysis did not reveal a significant difference between the two groups over the future importance of any of the topic areas identified within the materials subject area.



Table 16. -- Comparison of manufacturing managers and manufacturing educators in respect to the future importance of six subject areas in materials.

MANOVA:	Wilks' lambda = .93838 F = 2.12309 F			2309 p=.	p = .052	
ANOVA:	Educators		Mar	agers		
	Mean	SD	Mean	SD	р	
	(n=38)		(n=163)			
Materials						
Intro to Engr Matl's	3.8684	0.8438	3.8062	0.7896	.667	
Non-destructive Test	3.3947	0.8555	3.6139	0.7676	.123	
Physical Metallurgy	3.2105	0.7760	3.4500	0.6740	.057	
Selection of Materials	3.6279	0.7807	3.7688	0.7952	.438	
Polymer Materials	4.0789	0.8181	4.0123	0.8164	.651	
Polymeric Composites	4.2105	0.8107	4.0000	0.8389	.163	

Summary of Hypothesis 5. The two groups held similar views regarding the level of instruction desired and the future importance of materials as a subject area within the manufacturing engineering technology curriculum. However, they differed over the importance of materials within the curriculum. Educators perceived the introductory engineering materials course to be more important than did the managers. Hypothesis 5-A was rejected and hypotheses 5-B and 5-C were not rejected.

Hypothesis 6

Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of manufacturing processes within the recommended manufacturing engineering technology curriculum in respect to:



- a. importance
- b. desired level of instruction
- c. future importance

The first part of the hypothesis attempted to determine if the two groups differed in respect to the importance of manufacturing processes in the manufacturing engineering technology curriculum. MANOVA was used as a test of significance for the seven topic areas related to this hypothesis. A Wilks' lambda value of .86051 produced an F-value of 4.4694 and a probability of .0001 (Table 17). Thus, there was a significant difference between the two groups in respect to their view of the importance of manufacturing processes in the manufacturing engineering technology curriculum. Hypothesis 6-A was rejected.

Table 17. -- Comparison of manufacturing managers and manufacturing educators in respect to the importance of seven subject areas in manufacturing processes.

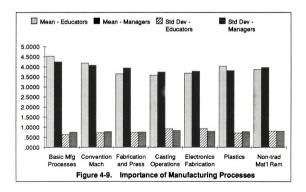
MANOVA:	Wilks' lam	bda = .8605	1 F = 4.46	94 p = .0	0001*	
ANOVA:	Educ	cators	Man	agers		
	Mean	SD	Mean	SD	р	
	(n=	=38)	(n=	:163)	•	
Manufacturing Processes	;					
Basic Mfg Processes	4.5263	0.6467	4.2531	.7561	.041	
Conventional Mach	4.1842	0.7299	4.0798	.7776	.452	
Fabrication and Press	3.6579	0.7453	3.9444	.7638	.038	
Casting Operations	3.5789	0.9192	3.7423	.8358	.288	
Electronics Fabrication	3.6842	0.9330	3.7840	.7913	.500	
Plastics	4.0263	0.7161	3.8148	.7795	.128	
Non-trad Mat'l Rem	3.8684	0.8111	3.9689	.8045	.489	

^{*}Significant at or beyond the .05 level.



Table 17 shows the two topic areas in this subject area over which the two groups differed significantly. The ANOVA test of significance isolated basic manufacturing processes and fabrication and press works. The educators perceived the basic manufacturing processes course to be significantly (p = .041) more important (mean = 4.5263) than did the industrial managers (mean = 4.2531). However, the managers perceived the fabrication and press works topic to be significantly (p = .038) more important (mean = 3.9444 vs. 3.6579).

Figure 4-9 illustrates the tighter standard deviation of the educators' responses regarding the basic manufacturing processes topic and the clear difference in the means of the two groups regarding the fabrication and press works topic.





The second part of the hypothesis attempted to determine if the two groups differed in respect to the level of instruction needed in manufacturing processes within the manufacturing engineering technology curriculum. MANOVA was used to analyze the seven topic areas identified as part of the manufacturing processes subject area. A Wilks' lambda value of .96733 yielded an F-value of .93105 and a probability of .484 (Table 18). Therefore, there was no significant difference in the views of both groups in respect to the level of instruction needed in manufacturing processes within the manufacturing engineering technology curriculum. Hypothesis 6-B was not rejected.

Table 18. -- Comparison of manufacturing managers and manufacturing educators in respect to the level of instruction needed in seven subject areas in manufacturing processes.

MANOVA:	Wilks' lam	bda = .9673	3 F = .931	05 p = .484	4
ANOVA:	Educ	ators	Mar	agers	
	Mean	SD	Mean	SD	р
	(n=38) (n=163)				
Manufacturing Processes	3				
Basic Mfg Processes	3.4865	0.7577	3.5399	0.7049	.679
Conventional Mach	3.5406	0.7917	3.5521	0.6773	.927
Fabrication and Press	3.3243	0.8072	3.5247	0.6685	.112
Casting Operations	3.3513	0.8452	3.4724	0.7313	.374
Electronics Fabrication	3.2162	0.9339	3.2919	0.7424	.591
Plastics	3.2973	0.7302	3.3025	0.6582	.966
Non-trad Mat'l Rem	3.2973	0.6922	3.3025	0.7294	.968



The ANOVA analysis did not reveal a significant difference between the groups over the level of instruction needed for any of the topics identified in the manufacturing processes subject area.

The third part of the hypothesis attempted to determine whether the two groups held similar views about the future importance of manufacturing processes within the manufacturing engineering technology curriculum. MANOVA was used to examine the seven topic areas related to this hypothesis. A Wilks' lambda value of .94456 produced an F-value of 1.61843 and a probability of .132 (Table 19). Therefore, there was no significant difference in the perceptions of both groups regarding the future importance of the manufacturing processes subject area within the manufacturing engineering technology curriculum. Hypothesis 6-C was not rejected.

Table 19. -- Comparison of manufacturing managers and manufacturing educators in respect to the future importance of seven subject areas in design for manufacturing processes.

MANOVA:	Wilks' lam	bda = .9445	6 F = 1.6	1843 p=.	132
ANOVA:	Educ	ators	Man	agers	
	Mean	SD	Mean	SD	р
	(n=38)		(n=	163)	
Manufacturing Processes	3				
Basic Mfg Processes	3.3947	0.7181	3.7160	0.8496	.032
Conventional Mach	3.1842	0.5626	3.4704	0.8356	.119
Fabrication and Press	3.0541	0.4618	3.4348	0.7268	.002
Casting Operations	3.1053	0.6893	3.2901	0.7753	.178
Electronics Fabrication	3.7895	0.8433	3.9062	0.7519	.401
Plastics	3.8947	0.8941	3.9188	0.7534	.865
Non-trad Mat'l Rem	3.9737	0.6773	4.1500	0.7794	.200

While the differences were not significant enough to impact the MA-NOVA test of significance for the subject area, the ANOVA test identified two topic areas which the two groups viewed significantly different: basic manufacturing processes (p = .032) and fabrication and press works (p = .002). The educators (mean = 3.3947) perceived, that in the future, basic manufacturing processes would not be as important as the managers (mean = 3.7160) perceived it to be. The managers, however, perceived the future importance of fabrication and press works (mean = 3.4348) to be increasingly important while the educators believed that it would stay about the same (mean = 3.0541). Interestingly, the two groups differed over these topics in hypothesis 6-A. However, the educators reversed their position regarding the basic manufacturing processes topic area. In contrast with the high ratings (nearly "Very Important") the educators gave the topic area in hypothesis 6-A, this response indicates that they perceived the topic diminishing in importance while the managers did not.

Summary of Hypothesis 6. The two groups held similar views about the level of instruction needed and the future importance of the manufacturing processes topic areas within the manufacturing engineering technology curriculum. They differed significantly over the importance of manufacturing processes in the curriculum. Managers perceived that fabrication and press works were more important, while educators perceived that basic manufacturing processes were more important. The educators perceived the future importance of basic manufacturing processes to be considerably less, when hypothesis 6-A and 6-C are compared. Hypothesis 6-A was rejected, and hypotheses 6-B and 6-C were not rejected.



Hypothesis 7

Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of manufacturing systems and automation within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

The first part of the hypothesis attempted to determine if the two groups differed in respect to the importance of manufacturing systems and automation within the manufacturing engineering technology curriculum. MANOVA was used as a test of significance for the seventeen topic areas related to this hypothesis. A Wilks' lambda of .86170 yielded an F-value of 1.72768 and a probability of .014 (Table 20). Thus, there was a significant difference between the two groups in respect to their perception of the importance of manufacturing systems and automation within the manufacturing engineering technology curriculum. Hypothesis 7-A was rejected.

The ANOVA test of significance identified three topics over which the two groups differed. Table 20 shows that the two groups differed significantly over PLC operation and programming (p = .017), systems integration (p = .044), and computer integrated manufacturing (p = .007). The educators perceived all three of these topics to be more important than did the managers. Figure 4-10 graphically illustrates the means and the standard deviations of the responses from both groups. The difference in the perceived importance of computer integrated manufacturing is validated by the smaller standard deviation in the educators response and the similar difference in the means of similar topics. Futhermore, the two groups rated both statistical



process control and computer aided manufacturing between "Important" and "Very Important." No topic received a mean rating from either group less than "Moderately Important" (lowest mean = 3.3421 for expert systems by the educators).

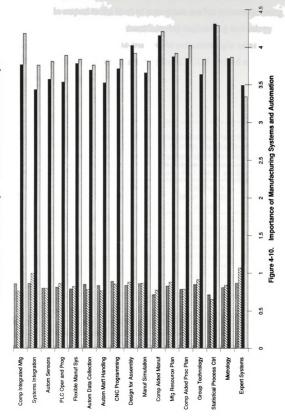
Table 20. -- Comparison of manufacturing managers and manufacturing educators in respect to the importance of seventeen subject areas in manufacturing systems and automation.

MANOVA:	Wilks' lam	bda = .8617	70 F = 1.7	2768 p = .	041*
ANOVA:	Educators		Mar	agers	
	Mean	SD	Mean	SD	р
	(n=38)		(n=	(n=163)	
Mfg Systems and Automa	ition				
Expert Systems	3.3421	1.0724	3.4938	0.8696	.356
Metrology	3.8684	0.8438	3.8528	0.8107	.915
Statistical Process Ctrl	4.2895	0.6538	4.3129	0.7160	.854
Group Technology	3.8421	0.9161	3.6380	0.8522	.192
Comp Aided Proc Plan	4.0263	0.7880	3.8528	0.7875	.223
Mfg Resource Plan	3.9211	0.8817	3.8765	0.8297	.769
Comp Aided Manuf	4.2105	0.7765	4.1553	0.7163	.674
Manuf Simulation	3.8158	0.8654	3.6584	0.8614	.312
Design for Assembly	3.9211	0.8817	4.0247	0.8385	.498
CNC Programming	3.8421	0.8551	3.7143	0.8919	.424
Autom Mat'l Handling	3.8158	0.7660	3.5283	0.8375	.054
Autom Data Collection	3.7632	0.7862	3.6975	0.8541	.666
Flexible Manuf Sys	3.8421	0.8229	3.7840	0.7913	.686
PLC Oper and Prog	3.8947	0.8634	3.5375	0.8156	.017
Autom Sensors	3.8108	0.7999	3.5732	0.8028	.102
Systems Integration	3.7632	0.9982	3.4375	0.8656	.044
Comp Integrated Mfg	4.1842	0.7660	3.7688	0.8623	.007

^{*}Significant at or beyond the .05 level.









The second part of this hypothesis attempted to determine if the two groups differed in respect to the level of instruction needed in manufacturing systems and automation within the manufacturing engineering technology curriculum. MANOVA was used to analyze the seventeen topic areas related to this hypothesis. A Wilks' lambda value of .90458 yielded an F-value of 1.1355 and a probability of .323 (Table 21).

Table 21. -- Comparison of manufacturing managers and manufacturing educators in respect to the level of instruction needed in seventeen subject areas in manufacturing systems and automation.

MANOVA:	Wilks' lam	bda = .9045	8 F = 1.13	3555 p = .3	23
ANOVA:	Edu	cators	Mar	agers	
	Mean	SD	Mean	SD	р
	(n=	=38)	(n=	=163)	
Mfg Systems and Automa	ation				
Expert Systems	3.2368	0.9134	2.9752	0.7449	.064
Metrology	3.3243	0.7372	3.3620	0.6462	.753
Statistical Process Ctrl	3.2632	0.7235	3.4136	0.6726	.222
Group Technology	3.2632	0.8601	3.2270	0.7311	.791
Comp Aided Proc Plan	3.3947	0.8233	3.3374	0.7952	.691
Mfg Resource Plan	3.3158	0.8732	3.2638	0.7684	.715
Comp Aided Manuf	3.3684	0.7505	3.4783	0.7378	.411
Manuf Simulation	3.2973	0.7302	3.2037	0.7868	.504
Design for Assembly	3.3513	0.7786	3.4506	0.7375	.461
CNC Programming	3.3947	0.7898	3.4506	0.7702	.689
Autom Mat'l Handling	3.2632	0.7947	3.3270	0.7738	.649
Autom Data Collection	3.2895	0.7318	3.2407	0.7270	.711
Flexible Manuf Sys	3.2432	0.7852	3.2761	0.7140	.802
PLC Oper and Prog	3.5000	0.6472	3.2422	0.8072	.068
Autom Sensors	3.3243	0.6598	3.2089	0.8466	.433
Systems Integration	3.1579	0.8861	3.0311	0.8272	.402
Comp Integrated Mfg	3.3158	0.7748	3.2174	0.8142	.499

Therefore, there was no significant difference between the two groups in respect to the level of instruction needed for manufacturing systems and automation subject areas within the manufacturing engineering technology curriculum. Hypothesis 7-B was not rejected.

The ANOVA analysis of the individual topic areas did not isolate a topic that the two groups viewed differently in respect to the level of instruction needed. The means from both groups remained between 2.9752 and 3.5000 (between an "Equal Balance" to "Mostly Practical").

The third part of the hypothesis attempted to determine whether the two groups held similar views about the future importance of manufacturing systems and automation within the manufacturing engineering technology curriculum. MANOVA was used to examine the seventeen topic areas related to this hypothesis. A Wilks' lambda value of .83210 yielded an F-value of 2.17204 and a probability of .006 (Table 22). Thus, there was a significant difference between the two groups' perspective about the future importance of the seven topic areas associated with manufacturing systems and automation. Hypothesis 7-C was rejected.

The ANOVA analysis revealed a significant difference in two topic areas: metrology (p = .032) and statistical process control (p = .001). The managers perceived that metrology (mean = 3.8827) would be more important in the future than did the educators (mean = 3.5676); however, the differences were greater regarding statistical process control (mean = 4.4074 vs. 3.9211). Furthermore, the standard deviation of the managers' responses was smaller, indicating a more unified agreement among the managers.

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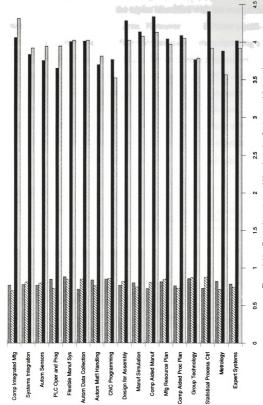
Table 22. -- Comparison of manufacturing managers and manufacturing educators in respect to the future importance of seventeen subject areas in manufacturing systems and automation.

MANOVA:	Wilks' lam	ambda = .83210 F = 2.1		17204 p = .006*	
ANOVA:	Educ	cators	Managers		
	Mean	SD	Mean	SD	P
	(n=38) (n=163)				
Mfg Systems and Automa	ation				
Expert Systems	3.9211	0.7491	4.0188	0.7894	.489
Metrology	3.5676	0.7181	3.8827	0.8269	.032
Statistical Process Ctrl	3.9211	0.8817	4.4074	0.7333	.001
Group Technology	3.7895	0.8748	3.7702	0.8624	.902
Comp Aided Proc Plan	4.0526	0.7333	4.0864	0.7649	.805
Mfg Resource Plan	3.9730	0.8538	4.0438	0.8191	.635
Comp Aided Manuf	4.1316	0.8111	4.3375	0.7277	.126
Manuf Simulation	4.0789	0.7491	4.1375	0.8050	.683
Design for Assembly	4.0263	0.8216	4.2840	0.7736	.069
CNC Programming	3.5263	0.8617	3.7702	0.8553	.116
Autom Mat'l Handling	3.8158	0.7660	3.7007	0.8423	.441
Autom Data Collection	4.0263	0.8538	4.0123	0.7200	.917
Flexible Manuf Sys	4.0263	0.8538	4.0062	0.8854	.899
PLC Oper and Prog	3.9474	0.7333	3.6541	0.8534	.052
Autom Sensors	3.9459	0.8036	3.7564	0.7728	.178
Systems Integration	3.9211	0.8181	3.8365	0.7847	.554
Comp Integrated Mfg	4.3158	0.7016	4.0625	0.7753	.067

^{*}Significant at or beyond the .05 level.

Figure 4-11 graphically illustrates the differences in the means and standard deviations of both groups. Compared to the current importance of expert systems (hypothesis 7-A, Figure 4-10), both groups predicted that the topic will be increasing in importance. Several other topics were perceived as increasing by both groups: computer aided process planning, manufacturing resource planning, computer aided manufacturing, design for assembly and computer integrated manufacturing.





Mean - Educators
Managers
Std Dev - Educators
Std Dev - Managers

Figure 4-11. Future Importance of Manufacturing Systems and Automation



Summary of Hypothesis 7. The two groups held similar views about the level of instruction needed for the topics identified with the manufacturing systems and automation subject area. However, they differed significantly over the importance and the future importance of manufacturing systems and automation within the manufacturing engineering technology curriculum. Educators perceived the highly automated topics (PLC operation and programming, systems integration, computer integrated manufacturing) as more important than did the manufacturing managers. However, the managers believed that statistical process control and metrology would increase in future importance to a greater extent than did the educators. Hypothesis 7-A and 7-C were rejected. Hypothesis 7-B was not rejected.

Hypothesis 8

Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of *controls* within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

The first part of this hypothesis attempted to determine if the two groups differed in respect to the importance of controls in the manufacturing engineering technology curriculum. MANOVA was used as a test of significance for the three topics related to this hypothesis. A Wilks' lambda value of .98537 produced an F-value of .95713 and a probability of .406 (Table 23). Thus, the two groups did not differ significantly in respect to the importance of controls in the manufacturing engineering technology curriculum. Hypothesis 8-A was not rejected.



The ANOVA analysis (Table 23) did not reveal a significant difference between the groups in respect to the importance of the three topics identified under the subject area of controls. Both groups felt all three topics were "Moderately Important" to "Important."

Table 23. -- Comparison of manufacturing managers and manufacturing educators in respect to the importance of three subject areas in controls.

MANOVA:	Wilks' lam	bda = .9853	37 F = .97	513 p = .4	06
ANOVA:	Educators		Mar	Managers	
	Mean	SD	Mean	SD	р
	(n=38) (n=163)				
Controls					
Electrical/Electr Cntr'ls	3.7368	0.7947	3.5750	0.7978	.261
Fluid Power	3.6053	0.9165	3.4410	0.7605	.251
Contr'ls of Ind Auto	3.7105	0.8977	3.4596	0.8089	.093

The educators rated each topic consistently higher in importance than did the managers; however, the variance was similar for both groups.

The second part of this hypothesis attempted to determine if the two groups differed concerning the level of instruction needed in respect to the controls subject area within the manufacturing engineering technology curriculum. MANOVA was used to examine the three topics related to this hypothesis. A Wilks' lambda value of .99524 yielded an F-value of .31383 and a probability of .815 (Table 24).



Table 24. -- Comparison of manufacturing managers and manufacturing educators in respect to the level of instruction needed in three subject areas in controls.

MANOVA:	Wilks' lam	bda = .9952	24 F = .31	383 p = .8°	15
ANOVA:	Educators		Mar		
	Mean	SD	Mean	SD	р
	(n=38) (n=163)				
Controls					
Electrical/Electr Cntr'ls	3.2632	0.7947	3.1553	0.7163	.414
Fluid Power	3.2632	0.6851	3.1988	0.6923	.605
Contr'ls of Ind Auto	3.2105	0.7766	3.0870	0.7649	.372

Thus, there was not a significant difference between the two groups in respect to the level of instruction needed for the controls subject area within the manufacturing engineering technology curriculum. Hypothesis 8-B was not rejected.

As Table 24 shows, the ANOVA analysis did not identify a significant difference over any of the three topics listed. The means of the responses of both groups are very close and the standard deviations parallel the means.

The third part of this hypothesis attempted to determine if the two groups held similar views about the future of the controls subject area in the manufacturing engineering technology curriculum. The MANOVA analysis yielded a Wilks' lambda value of .98385, an F-value of 1.07797 and a probability of .360 (Table 25). Thus, the two groups did not differ significantly over the future of the controls subject area within the manufacturing engineering technology curriculum. Hypothesis 8-C was not rejected.

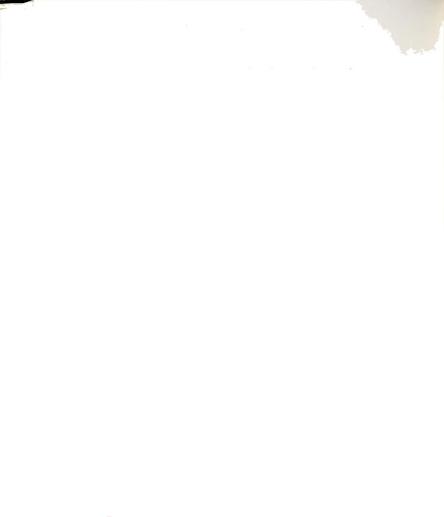


Table 25. — Comparison of manufacturing managers and manufacturing educators in respect to the future importance of three subject areas in controls.

MANOVA:	Wilks' lambda = .98385 Educators		F = 1.0	F = 1.07797 p =		
ANOVA:			Managers			
	Mean	SD	Mean	SD	р	
	(n=38) (n=163)					
Controls						
Electrical/Electr Cntr'ls	3.7368	0.8280	3.7547	0.7755	.900	
Fluid Power	3.2895	0.7679	3.3798	0.7167	.491	
Contr'ls of Ind Auto	3.8158	0.9545	3.6604	0.7684	.286	

The ANOVA analysis (Table 25) found that the two groups did not differ significantly over the future importance of any of the topic areas listed as part of the controls subject area. They held similar views about the future importance of all three topics.

<u>Summary of Hypothesis 8</u>. The two groups did not differ over any of the individual topics within all three categories of the subject area. They held similar views about the importance, the level of instruction needed, and the future importance of the controls subject area within the manufacturing engineering technology curriculum. Hypotheses 8-A, 8-B, and 8-C were not rejected.



Hypothesis 9

Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of manufacturing management, productivity, and quality within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

The first part of this hypothesis attempted to determine if the two groups differed in respect to the importance of manufacturing management, productivity, and quality subjects in the manufacturing engineering technology curriculum. MANOVA was used to analyze the eight topic areas associated with the subject in this hypothesis. A Wilks' lambda of .92356 yielded an F-value of 1.98645 and a probability of .050 (Table 26).

Table 26. -- Comparison of manufacturing managers and manufacturing educators in respect to the importance of eight subject areas in manufacturing management, productivity and quality.

MANOVA:	Wilks' lam	bda = .9235	6 F = 1.98	645 p=	.050*
ANOVA:	Educators		Man	agers	
	Mean	SD	Mean	SD	р
	(n=38)		(n=163)		
Mfg Mgmt, Productivity a	nd Quality				
Business Mgmt	3.2895	0.8977	3.5370	.8545	.113
Motion & Time Study	3.0000	1.0134	3.3580	.7905	.018
Proc Plann and Design	3.6316	0.7857	3.9202	.8387	.055
Plant Layout	3.5000	0.8302	3.7531	.7459	.067
Tolerance Charting	3.4211	0.9482	3.8037	.8001	.011
Quality in Manuf	4.2105	0.7410	4.2147	.7836	.976
Organizational Behav	3.5789	0.8893	3.8650	.9130	.082
Engr Economics	4.0263	0.7880	4.0309	.8045	.975

^{*}Significant at or beyond the .05 level.

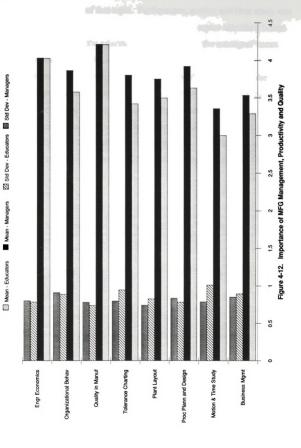


Since a MANOVA analysis of this subject area yielded a probability of exactly .050, strict interpretation would conclude that a difference does not exist between the two groups in respect to the importance of the manufacturing, productivity and quality subject area because the probability value is not less than .05. However, other factors suggest that the risk of committing a Type I error by concluding that there is a difference between the two groups, when there really is not, is negligible. The two groups differ significantly over the other two categories of this subject area, and they differ significantly over all but two of the categories in regard to the future importance of the subject area. Thus, this investigator finds that there is a difference between educators and manufacturing managers over the importance of the manufacturing management, productivity and quality subject area within the manufacturing engineering technology curriculum. Hypothesis 9-A is rejected.

As Table 26 shows, the ANOVA analysis of the individual topic areas located two topics over which the two groups differed significantly: motion and time study (p = .018) and tolerance charting (p = .011).

Figure 4-12 graphically illustrates the differences in the mean responses and standard deviations of the responses from both groups. The mean responses of the managers were higher than those of the educators in every topic area identified. The very close mean responses of the two groups in quality in manufacturing (educators = 4.2105 and the managers = 4.2147) and in engineering economics (educators = 4.0263 and the managers = 4.0309) responses suggest that the groups are quite unified in their views about the importance of these topics. The larger standard deviation in the educators' responses regarding motion and time study suggests that the group







is not unified in view of that topic. Furthermore, motion and time study was viewed by both groups as the least important of the topics identified (mean of the responses from the educators was 3.000 while the managers' mean of the responses was 3.3580).

The second part of this hypothesis attempted to determine if the two groups differed in respect to the level of instruction needed for the manufacturing management, productivity and quality subject area within the manufacturing engineering technology curriculum. MANOVA was used to analyze the eight topic areas related to this hypothesis. A Wilks' lambda value of .92032 yielded an F-value of 2.07782 and a probability of .040 (Table 27).

Table 27. -- Comparison of manufacturing managers and manufacturing educators in respect to the level of instruction needed in eight areas of manufacturing management, productivity and quality.

MANOVA:	Wilks' lambda = .92032 F = 2.07782 p = .040*					
ANOVA:	Educators		Mar			
	Mean	SD	Mean	SD	р	
	(n=38)		(n=163)			
Mfg Mgmt, Productivity a	nd Quality					
Business Mgmt	3.0263	0.8849	3.0679	0.7945	.776	
Motion & Time Study	3.1111	0.9523	3.1914	0.7741	.583	
Proc Plann and Design	3.0526	0.8683	3.3252	0.6748	.036	
Plant Layout	3.0263	0.7880	3.3436	0.6973	.015	
Tolerance Charting	2.9474	0.8637	3.3252	0.7444	.006	
Quality in Manuf	3.3158	0.6619	3.4172	0.7185	.428	
Organizational Behav	3.0000	0.9300	3.2147	0.6826	.106	
Engr Economics	3.1316	0.9056	3.2469	0.6944	.387	

^{*}Significant at or beyond the .05 level.

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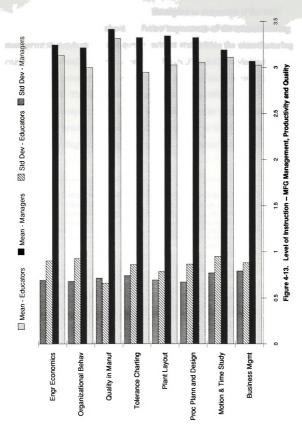
Thus, the two groups differed significantly over the level of instruction needed for the manufacturing management, productivity and quality subject area within the manufacturing engineering technology curriculum. Hypothesis 9-B was rejected.

Table 27 shows that the two groups differed significantly over the level of instruction needed in three of the eight topic areas identified as part of the manufacturing management, productivity and quality subject area. Those three topics were: process planning and design (p = .036), plant layout (p = .015), and tolerance charting (p = .006). In each case, the educators preferred a balanced mix of theory and practice, while the managers preferred a more practical level of instruction. The two groups held similar beliefs about the level of instruction needed in business management. The mean of the educators' reponses was .30263 and the mean of the managers' responses was 3.0679.

Figure 4-13 graphically illustrates that the managers preferred a more practical level of instruction than didthe educators in every topic area. The three topic areas where there was a significant difference (process planning and design, plant layout, and tolerance charting) were chosen by the educators as appropriate topic areas for a more balanced level of instruction. The managers preferred more practical levels of instruction.

Also, illustrated in Figure 4-13 are the larger standard deviations in the responses of the educators. In only one category did the responses of the educators produce a smaller standard deviation than the managers, quality in manufacturing (.6619 vs. .7185). The consistently smaller standard deviation in the managers' responses suggests that the managers were more unified than the educators over the level of instruction needed in this subject.







The third part of this hypothesis attempted to determine if the two groups held similar views about the future importance of the manufacturing management, productivity and quality subject area within the manufacturing engineering technology curriculum. The MANOVA analysis yielded a Wilks' lambda value of .9217, an F-value of 2.03880, and a probability of .044 (Table 28). Therefore, there was a significant difference between the two groups in respect to the future importance of the manufacturing management, productivity and quality subject area within the manufacturing engineering technology curriculum. Hypothesis 9-C was rejected.

Table 28. -- Comparison of manufacturing managers and manufacturing educators in respect to the future importance of eight subject areas in manufacturing management, productivity and quality.

MANOVA:	Wilks' lambda = .92170 F = 2.03880 p = .044*					
ANOVA:	Educ	cators	Mar	agers		
	Mean	SD	Mean	SD	р	
	(n=38)		(n=163)			
Mfg Mgmt, Productivity a	nd Quality					
Business Mgmt	3.2105	0.8107	3.6211	0.7110	.002	
Motion & Time Study	2.7838	0.9045	3.0625	0.8656	.078	
Proc Plann and Design	3.4474	0.7240	3.7901	0.8198	.019	
Plant Layout	3.2632	0.8909	3.5864	0.7589	.023	
Tolerance Charting	3.2632	0.9208	3.7716	0.8908	.002	
Quality in Manuf	4.2162	0.8426	4.3457	0.7643	.358	
Organizational Behav	3.7027	0.8964	3.9815	0.8423	.071	
Engr Economics	3.7838	0.8426	3.9938	0.8202	.159	

^{*}Significant at or beyond the .05 level.



A futher analysis using ANOVA isolated four topic areas where the two groups differed significantly over the future importance of these topic areas: business management (p = .002), process planning and design (p = .019), plant layout (p = .023), and tolerance charting (p = .002).

In the four topic areas where the two groups differed significantly, the mean of the managers' responses indicated that they perceived these topic areas to be increasing in importance to a greater degree than their educational counterparts. A comparison of the means reveals this consistent trend: business management (3.2105 - educators, 3.6211 - managers), process planning and design (3.4474 - educators, 3.7901 - managers), plant layout (3.2632 - educators, 3.5864 - managers). In fact, managers perceived all eight categories to be increasing in importance significantly more than did educators.

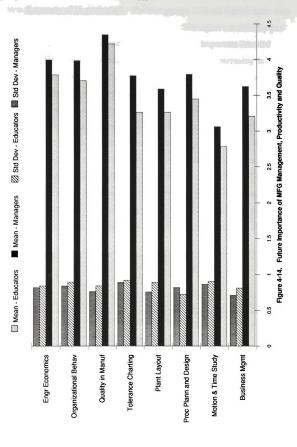
Figure 4-14 graphically illustrates the differences in the mean of the responses of both groups and the standard deviations of the responses of both groups for all eight topics. With the exception of process planning and design, the educators were not as unified in their belief as were the managers regarding the future importance of the topics listed.

The only topic perceived by either group to be leaning toward "Decreasing Some," was motion and time study. Interestingly, both groups rated it the lowest of the eight topics, and managers did not significantly differ with the educators. The educators were more consistent in their ratings of motion and time study in both hypotheses addressing the importance of motion and time study (Hypotheses 9-A and 9-C). The mean of the managers' responses suggests that they believe the topic will decrease in importance.

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Summary of Hypothesis 9. The two groups differed significantly over all three categories relating to this subject area. Managers consistently perceived that all of the topic areas were currently more important than did educators. Furthermore, managers perceived them to be increasing in importance in the future at a distinctly greater rate than did educators. Managers differed significantly with educators over the importance of motion and time study and process planning and design. Managers perceived them to be more important than did the educators. Furthermore, they differed significantly over the level of instruction needed for the three topic areas. Managers preferred a more practical level of instruction than did educators. The two groups also differed significantly over the future importance of four of the eight topic areas. Again, managers consistently perceived the topics to be of greater importance in the future than did educators. All three of the hypotheses related to this subject area were rejected (Hypotheses 9-A, 9-B, and 9-C).

Hypothesis 10

Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of *computer applications* within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

The first part of this hypothesis attempted to determine if the two groups differed in respect to the importance of computer applications in the manufacturing engineering technology curriculum. MANOVA was used as a test of significance for the seven topic areas related to this hypothesis.



A Wilks' lambda value of .94060 yielded an F-value of 1.7411 and a probability of .102 (Table 29). Thus, the two groups did not differ with respect to the importance of the computer applications subject area within the manufacturing engineering technology curriculum. Hypothesis 10-A was not rejected.

Table 29. -- Comparison of manufacturing managers and manufacturing educators in respect to the importance of seven subject areas in computer applications.

MANOVA:			60 F = 1.74		.102
ANOVA:	Educators		Man		
	Mean	SD	Mean	SD	р
	(n=38)		(n=163)		
Computer Applications					
BASIC Programming	3.3684	1.0246	3.2975	.9782	.690
Fortran Programming	3.0526	1.0120	2.8291	.9375	.194
"C" Programming	3.4722	1.1025	2.9678	.8778	.003
Wordprocessing	3.8378	0.8547	3.6918	.9293	.377
Spreadsheet	4.0000	0.8699	3.9441	.8031	.704
Database	3.7632	1.1012	3.7405	.8691	.891
Svs Selection & Eval	3.6579	0.9939	3.4459	.8706	.190

The ANOVA analysis (Table 29) isolated one topic area over which the two groups differed significantly: "C" programming (p = .003). The managers did not perceive the topic to be as important as did educators (means of educators and managers, 3.4722 and 2.9678, respectively). The two groups viewed the importance of spreadsheets similarly. The topic was rated the highest by both groups. The larger standard deviation of the educators' responses to the several topics suggests that there was a larger range of



responses from that group. Both groups did rate fortran programming lower than any of the other topics listed.

The second part of the hypothesis attempted to determine if the two groups differed over the level of instruction needed for computer applications in the manufacturing engineering technology curriculum. MANOVA was used to examine the seven topics related to this hypothesis. A Wilks' lambda value of .95874 yielded an F-value of 1.18657 and a probability of .312 (Table 30). Thus, the two groups did not differ over the level of instruction needed for computer applications within the manufacturing engineering technology curriculum. Hypothesis 10-B was not rejected.

Table 30. -- Comparison of manufacturing managers and manufacturing educators in respect to the level of instruction needed in seven subject areas in computer applications.

MANOVA:	Wilks' lam	bda = .9587	74 F = 1.18	657 p = .3	12
ANOVA:	Educators		Mar		
	Mean	SD	Mean	SD	р
	(n=	(n=38) (n=163)		=163)	
Computer Applications					
BASIC Programming	3.3684	0.7136	3.1307	0.8727	.120
Fortran Programming	3.2105	0.8748	2.9281	0.9629	.099
"C" Programming	3.3143	0.8936	2.9868	0.8957	.044
Wordprocessing	3.5946	0.8841	3.6169	0.8621	.887
Spreadsheet	3.5526	0.8285	3.6125	0.8818	.704
Database	3.5000	0.8302	3.4500	0.8944	.754
Sys Selection & Eval	3.1579	1.0007	3.2116	0.8241	.729



The ANOVA analysis (Table 30) isolated one topic over which the two groups differed concerning the level of instruction needed for computer applications: "C" programming (p = .044). The educators preferred a more practical level of instruction (3.3143) for this topic while the managers perceived the topic (2.9868) as leaning toward "Mostly Theory."

Wordprocessing and spreadsheet activities were perceived by both groups as leaning toward "Most Practical" levels of instruction.

The third part of this hypothesis attempted to determine if the two groups held similar views about the future importance of computer applications within the manufacturing engineering technology curriculum. MANOVA was used to analyze all seven topics related to this hypothesis. A Wilks' lambda value of .88137 yielded an F-value of 3.71094 and a probability of .001 (Table 31).

Table 31. -- Comparison of manufacturing managers and manufacturing educators in respect to the future importance of seven subject areas in design for computer applications.

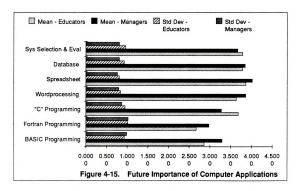
MANOVA:	Wilks' lambda = .88137 F = 3.71094 p = .001*				
ANOVA:	Educators		Mar		
	Mean	SD	Mean	SD	р
	(n=38)		(n=163)		•
Computer Applications					
BASIC Programming	2.8649	0.9347	3.2960	0.9928	.016
Fortran Programming	2.6757	1.0149	2.9802	1.0272	.101
"C" Programming	3.6857	0.9521	3.2800	0.8757	.012
Wordprocessing	3.6389	0.8432	3.8628	0.8017	.126
Spreadsheet	3.8684	0.8111	4.0255	0.7694	.263
Database	3.7895	0.9346	3.8544	0.8152	.668
Sys Selection & Eval	3.7895	0.9630	3.6732	0.8152	.446

^{*}Significant at or beyond the .05 level.



Thus, the two groups differed significantly over the future importance of computer applications in the manufacturing engineering technology curriculum. Hypothesis 10-C was rejected.

The ANOVA analysis (Table 31) isolated two topics over which the two groups differed significantly: BASIC programming (p = .016) and "C" programming (p = .012). Figure 4-15 graphically illustrates that educators believed that BASIC programming (mean = 2.8649) would be "Decreasing Some" in importance in the future and managers believed it would be increasing some in importance (mean = 3.2960). Educators continued to differ with managers in respect to the future importance of "C" programming. They believed it would continue to increase in importance (mean = 3.6857) more significantly than do managers (mean = 3.2800). Furthermore, both groups believed that fortran programming would not be as important in the future.





Summary of Hypothesis 10. The two groups did not differ over the importance or the level of instruction needed for computer applications within the manufacturing engineering technology curriculum. They did differ over the future importance of computer applications in the curriculum. They differed significantly over the future of BASIC programming and "C" programming. Educators perceived BASIC programming as decreasing in importance while managers viewed it as increasing in importance. Both viewed "C" programming as increasing; however, educators viewed the change to be much more distinct. Hypotheses 10-A and 10-B were not rejected. Hypothesis 10-C was rejected.

Hypothesis 11

Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of a *capstone* experience within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

The first part of this hypothesis attempted to determine if the two groups held similar views about the importance of a capstone experience in the manufacturing engineering technology curriculum. The MANOVA analysis yielded a Wilks' lambda value of .94387, an F-value of 3.90505, and a probability of .010 (Table 32). Thus, the two groups did not hold similar views about the importance of the capstone experience in the manufacturing enginering technology curriculum. Hypothesis 11-A was rejected.



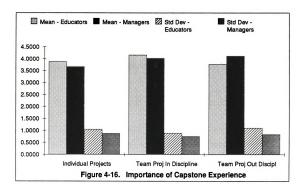
The ANOVA test of significance, related to each of the three topic areas within the subject area, found that the two groups differed significantly over the importance of team projects outside of the discipline (p = .029).

Table 32. -- Comparison of manufacturing managers and manufacturing educators in respect to the importance of three types of capstone experiences.

MANOVA:	Wilks' lam	bda = .9438	37 F = 3.9	0505 p=.	010*	
ANOVA:	Educators		Managers			
	Mean	SD	Mean	SD	р	
	(n=38) (n=163)		163)			
Capstone Experience						
Individual Projects	3.8684	1.0442	3.6582	0.8733	.200	
Team Proj In Discipline	4.1579	0.8861	4.0190	0.7574	.326	
Team Proj Out Discipl	3.7632	1.1012	4.1139	0.8313	.029	

^{*}Significant at or beyond the .05 level.

Figure 4-16 illustrates the significance of the differences between the two groups in respect to the mean of the responses and the standard deviation of the responses of both groups. The educators perceived that individual projects (mean = 3.8684) and team projects within the discipline (mean = 4.1579) were more important than team projects outside of the discipline (mean = 3.7632). Managers, however, rated team projects outside of the discipline the highest (mean = 4.1139) and individual projects (mean = 3.6582) as the least important of the three options. The standard deviation of the managers' responses suggests that they were in agreement about the importance of the three topics.



The second part of the hypothesis attempted to determine if the two groups differed in respect to the level of instruction needed for the capstone experience within the manufacturing engineering technology curriculum. The MANOVA test yielded a Wilks' lambda value of .91104, an F-value of 6.41192, and a probability of .0001 (Table 33). Thus, the two groups differed significantly over the level of instruction needed for the capstone experience within the manufacturing engineering technology curriculum. Hypothesis 11-B was rejected.

The ANOVA test of significance, related to the three topic areas, did not find that the two groups differed over any of the topics (Table 33). However, the F-value (6.41192), suggests that the ratio of the "between group variance" and the "within group variance" was high enough to indicate that



something other than chance has influenced the outcome of the multivariate analysis. The mutivariate analysis which produced a p value < .000, was the direct outcome of the size of the F-value over the three topic areas.

Even though the difference was not significant, the educators felt that the team project out of the discipline did not have to be as practical as did the managers. The managers were very consistent in their ratings of all three topic areas.

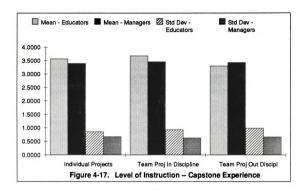
Table 33. -- Comparison of manufacturing managers and manufacturing educators in respect to the level of instruction needed in each of the three capstone experiences.

MANOVA:	Wilks' lam	bda = .9110	4 F= 6.4	11192 p = .0	0001*
ANOVA:	Educators		Mar	Managers	
	Mean	SD	Mean	SD	р
	(n=38)		(n=163)		
Capstone Experience					
Individual Projects	3.5676	0.8555	3.3949	0.6736	.179
Team Proj In Discipline	3.6757	0.9316	3.4586	0.6235	.083
Team Proj Out Discipl	3.2973	0.9827	3.4268	0.6593	.326

^{*}Significant at or beyond the .05 level.

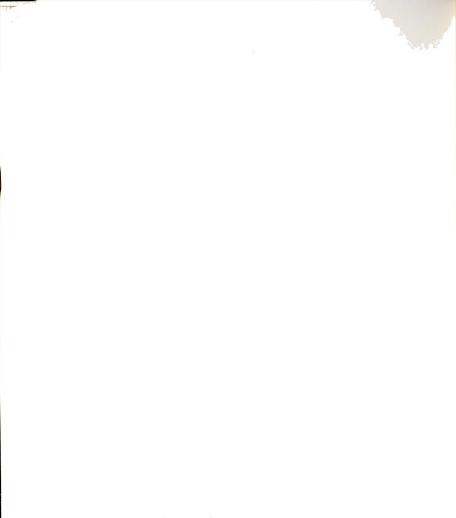
Figure 4-17 illustrates the mean and standard deviation differences between the responses of the two groups. The larger standard deviation of the educators' responses suggests that there was less agreement among the group.





The third part of the hypothesis attempted to determine if the two groups held similar views about the future importance of a capstone experience within the manufacturing engineering technology curriculum. The MANOVA test yielded a Wilks' lambda value of .97325, an F-value of 1.80483, and a probability of .148 (Table 34). Thus, the two groups did not differ significantly in respect to the future importance of a capstone experience within the manufacturing engineering technology curriculum. Hypothesis 11-C was not rejected.

The ANOVA test of significance related to the three topic areas did not find that the groups differed over any of the topics in this subject area (Table 34). Both groups perceived team projects to be increasing in



importance, and the managers predicted that team projects outside of the discipline would dramatically increase in importance.

Table 34. -- Comparison of manufacturing managers and manufacturing educators in respect to the future importance of three types of capstone experiences.

MANOVA:	Wilks' lam	bda = .97325	F = 1.8	F = 1.80483 p = .148		
ANOVA:	Educators		Managers			
	Mean	SD	Mean	SD	р	
	(n=38)		(n=163)			
Capstone Experience						
Individual Projects	3.4211	1.0813	3.4936	0.8992	.667	
Team Proj In Discipline	4.0489	0.7844	3.9616	0.7608	.395	
Team Proj Out Discipl	4.0000	0.9864	4.1987	0.7488	.169	

Summary of Hypothesis 11. The two groups differed in respect to the importance and the level of instruction needed for the capstone experience within the manufacturing engineering technology curriculum. They agreed in respect to the future importance of the capstone experience. The managers perceived team projects outside of the discipline to be more important than did the managers. Although the groups did not differ significantly over an individual topic area in respect to the level of instruction needed, the multivariate analysis identified a high amount of "between group variance" versus "within group variance" activity, which produced the larger F- value. The large F-value indicates that there is a significant probability that the two groups differed. Hypotheses 11-A and 11-B were rejected. Hypothesis 11-C was not rejected.



Summary

The results of the statistical analysis for each of the eleven hypotheses were presented in this chapter. Multivariate analysis of variance and univariate analysis of variance were employed to analyze the data collected for the study.

Each of the eleven hypotheses were tested using three categories: importance of the subject area, level of instruction needed for the subject area, and future importance of the subject area. The topics within each of the eleven subject areas were identified by a prior Society of Manufacturing Engineering study.

Table 35 shows a summary of the accepted and rejected hypotheses. Only one hypothesis (Hypothesis 9) was rejected in all three categories and only one hypothesis (Hypothesis 8) was accepted in all three categories. The other nine had one or more rejected in at least one category.

No significant difference was found between the two groups in respect to the importance of the science and mathematics subject area. However, the two groups did differ over the level of instruction needed and the future importance of science and mathematics (Hypothesis 1).

Similarly, no statistical difference was found between the two groups in respect to the importance and future importance of communications. The groups did differ over the level of instruction needed within the subject area (Hypothesis 2).

The two groups differed significantly over the importance of humanities and social science in the curriculum. They held similar views about the level of instruction and the future importance of humanties and social

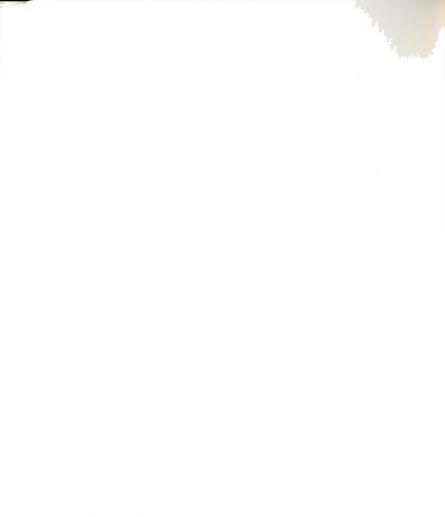


Table 35. -- Summary of the accepted and rejected hypotheses

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	Subject Area Importance	Level of Instruction	Future Importance
Hypothesis 1	Accepted	Rejected	Rejected
Hypothesis 2	Accepted	Rejected	Accepted
Hypothesis 3	Rejected	Accepted	Accepted
Hypothesis 4	Rejected	Accepted	Rejected
Hypothesis 5	Rejected	Accepted	Accepted
Hypothesis 6	Rejected	Accepted	Accepted
Hypothesis 7	Rejected	Accepted	Rejected
Hypothesis 8	Accepted	Accepted	Accepted
Hypothesis 9	Rejected	Rejected	Rejected
Hypothesis 10	Accepted	Accepted	Rejected
Hypothesis 11	Rejected	Rejected	Accepted



science in the curriculum (Hypothesis 3).

The groups differed significantly over the importance and future importance of design for production subjects. The two groups held similar views about the level of instruction needed in the subject area (Hypothesis 4).

The two groups differed significantly over the importance of materials in the curriculum; however, they held similar views about the level of instruction needed and the future importance of the subject area (Hypothesis 5).

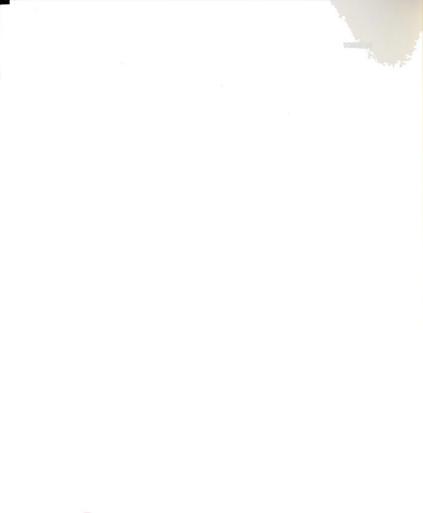
Similarly, the two groups differed significantly over the importance of the manufacturing processes subject area; however, they held similar views about the level of instruction needed and the future importance of the subject area (Hypothesis 6).

The groups significantly differed over the importance and the future importance of the manufacturing systems and automations subject area. They did hold similar views about the level of instruction needed for this subject (Hypothesis 7).

The groups held similar views about all three categories related to the controls subject area (Hypothesis 8).

The two groups differed significantly in all three categories related to the manufacturing management, productivity and quality subject area (Hypothesis 9).

In respect to the importance and the level of instruction need for computer applications, the two groups did not differ significantly. However, they did differ significantly over the future importance of the subject area (Hypothesis 10).



The importance and the level of instruction needed was viewed significantly different by the two groups. They did perceive the future importance of the subject area similarly (Hypothesis 11).

The two groups differed over the importance of a subject area in seven of the hypotheses. They differed over the level of instruction needed in four of the hypotheses. Finally, they differed over the future importance of the subject area in five hypotheses. A significant difference was discovered in 16 of the 33 (48.5 per cent) individual hypotheses.



CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A healthy manufacturing sector leads to a higher standard of living. The United States manufacturing sector is not healthy. The declining competitive position of U.S. manufacturing over the last two decades has been well-documented. The inability of American manufactured goods to effectively compete in international competition has prompted intense national soul-searching. Nearly every serious diagnostic effort eventually comes around to the issue of education.

The field of manufacturing is changing so rapidly that universities, like industries, are finding it difficult to keep up. Outdated equipment and facilities are typically associated with a curriculum designed for traditional production techniques. Modern manufacturing requires a radically different kind of engineer, an engineer educated and trained to alternate between an operations integrator, a manufacturing strategist, and a technical specialist.

The process of developing and revising the manufacturing engineering technology curricula at universities throughout the U.S. to respond to the national need is overwhelming. To expedite the needed change, manufacturing educators and manufacturing managers need to gain a better understanding of what subject areas are important, what level of instruction is needed, and what subject areas will be increasingly more important in the future. Furthermore, if the two groups recognize where they do significantly differ in respect to those categories, needed change will occur.



Summary

This study was designed to determine if manufacturing engineering technology faculty and manufacturing managers differ concerning the major categories and subject areas recommended by a Society of Manufacturing Engineers' task force for bachelor-level manufacturing engineering technology programs in respect to: 1) the importance of the subject area, 2) the desired level of instruction, and 3) the future importance of each subject area.

The principal question to be answered was whether or not the two groups differed over matters of curriculum. The assumption which accompanies this question is critical to this study: educators believe that they do not differ with manufacturing managers in respect to curriculum issues. If they were aware of a significant difference, they would change. Recognizing that a difference exists is often the first step to real change.

To determine if the two groups differed, eleven hypotheses were developed, which correlated to the eleven subject areas identified in the Society of Manufacturing Engineers' study. Each hypothesis examined several topic areas according to three categories: importance of the subject area, level of instruction needed for the subject area, and future importance of the subject area. The eleven hypotheses were:

<u>Hypothesis 1</u>. Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of *science and mathematics* within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance



<u>Hypothesis 2</u>. Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of *communications* within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

<u>Hypothesis 3</u>. Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of *humanities and social sciences* within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

<u>Hypothesis 4.</u> Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of *design for production* within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

<u>Hypothesis 5.</u> Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of *materials* within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

<u>Hypothesis 6</u>. Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of *manufacturing processes* within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

<u>Hypothesis 7</u>. Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of manufacturing systems and automation within the recommended manufacturing engineering technology curriculum in respect to:



- a. importance
- b. desired level of instruction
- c. future importance

<u>Hypothesis 8</u>. Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of *controls* within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

<u>Hypothesis 9</u>. Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of *manufacturing management*, productivity, and quality within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

<u>Hypothesis 10.</u> Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of *computer applications* within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

<u>Hypothesis 11</u>. Industrial manufacturing managers and manufacturing engineering technology faculty do not differ in their rating of a *capstone experience* within the recommended manufacturing engineering technology curriculum in respect to:

- a. importance
- b. desired level of instruction
- c. future importance

Literature

A search of the literature was conducted to discover prior research related to the hypotheses tested in this study. Due to the lack of directly related studies and references in the area targeted for this study, the review



of the literature considered elements that held logical ties. Those areas included: an overview of the changing world of manufacturing, evidence of the criticisms directed at engineering and manufacturing engineering education in the U.S., and a review of recent studies related to manufacturing education in general.

The literature supported the decline of American manufacturing over the last two decades, the concurrent growth of global competition during the era, and the projections for domestic manufacturing in the future. Apparent in the literature is the need for manufacturers to understand that they are competing for market share in a global arena. Every aspect of the manufacturing process must be analyzed and understood before companies can effectively compete with manufacturers around the world. Also, evident in the literature was a clear warning: "If something is not done, America's standard of living will continue to drop until all manufacturing is performed in some other country." Throughout the literature, executives continually cautioned readers -- "This is a war we cannot afford to lose."

One of the primary concerns expressed by manufacturing managers, in the literature, was the lack of properly trained manufacturing engineers. Education at all levels was severely criticized for becoming too theoretical and too isolated. Faculty were accused of being indifferent and out-of-touch. Most experts recommended a thorough revamping of the manufacturing engineering and manufacturing engineering technology curricula.

Seven studies were reviewed which dealt with the changing role of the manufacturing engineer and the curriculum needed to facilitate the change. The SME-commissioned studies explored the current status of the manufacturing engineering, the competencies needed by a graduate manufacturing

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engineer, and the projected role of the manufacturing engineer in the future. Recent work provided a list of courses and subject areas for an ideal manufacturing engineering technology curriculum. Additional studies examined specific curriculum topics, computer integrated manufacturing in the curriculum, and the needed competencies for aspects of a manufacturing-related curriculum. The implication in these studies was that the manufacturing engineer of the future will, not only need different competencies than our current university programs provide, but that educators need to listen more carefully to industrial experts when curriculum revisions are made. No studies were found which attempted to determine the of importance subject areas within the curriculum, the level of instruction needed, or the future importance of a subject area.

Methodology

Two populations were surveyed in this study. The first population of 8,512 industrial manufacturing managers was sampled using a list of 500 randomly generated subscribers to the Society of Manufacturing Engineers' *Manufacturing Engineering* magazine who lived in the United States and identified their job function as "Manufacturing Engineering Management." One-hundred sixty-three managers responded to the survey instrument, a response rate of 32.6 per cent.

The second population consisted of all the faculty who teach in accredited, bachelor-level manufacturing engineering technology programs in the United States and are listed in the 1990 edition of the Society of Manufacturing Engineers' "Directory of Manufacturing Education." The entire



population of 81 faculty were surveyed. Thirty-eight faculty returned the questionnaire, a response rate of 46.9 per cent.

Both groups were given the same questionnaire, except for separately requested demographic data. The questionnaire requested respondents to rank the importance, level of instruction needed, and the future importance of 80 topics divided into eleven subject areas. The subject areas and topics were adapted from the curriculum model developed by an SME study. Returned surveys were reviewed and the responses were entered into a formatted data base for easy transfer to the SPSS-X statistical analysis software.

Statistical analysis was completed using multivariate analysis of variance (MANOVA) and univariate analysis of variance (ANOVA). Each of the subject areas were subjected to three MANOVA analyses (importance of the subject area, level of instruction needed, and the future importance of the subject area) at a significance level of .05. Where significance was found, further topic analysis within a subject area and category was completed using univariate analysis (ANOVA). Three tables were developed for each hypothesis with Wilks' lambda, F-values, p-values, topic means and standard deviations for both groups, and p-values for topic area significance. A graph was developed to graphically illustrate differences in group response means and standard deviations for each subject area where significant difference occurred.

General Observations

There are two general observations regarding this study which are similar to other studies. First, just as Barnhart (1988) observed in his study,



topics expressed in general terms were ranked higher in importance than those which were more specifically defined. This is further illustrated by the differences noted over the three categories related to manufacturing management, productivity and quality. The two groups differed significantly over all three categories. Clearly, the managers were acutely aware of the topic areas and held rather strong opinions about the importance, level of instruction needed, and future importance of each area.

Secondly, there was greater agreement among the industrial managers than there was among the educators. In nearly every category and subject area, the variance of the managers' responses was lower than the variance of the educators' responses. Consistent with the findings of Taraman (1988), Barnhart (1988) and Foston (1984), the extensive differences among educators, regarding manufacturing-related curricula, is often reflected in their respective program content and the variety of opinions expressed at conferences. Programs are often developed around a faculty member's expertise.

Results

The first three hypotheses pertained to traditional *liberal studies* coursework in the curriculum. The two groups differed over the importance of humanities and social sciences, the level of instruction needed for science, mathematics and communications, and the future importance of science and mathematics. Specific differences were evident in the second calculus course and in the future importance of higher levels of mathematics. This is in agreement with Barnhart's (1988) findings and the comments of participants found in the *Curricula 2000* conference proceedings (SME, 1990a).

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Troxler (1989) also noted that manufacturing engineers were concerned that the advanced science and mathematics courses would force students out of the laboratory.

Do managers and educators differ within the design for production subject areas concerning the manufacturing engineering technology curriculum? The results clearly suggest this to be the case. They differed significantly over the importance and the future importance of several traditional design topics within the design for production subject area. This is in agreement with Barnhart's (1988) study. In his study of curricula, coursework in product design, kinematics, dynamics, descriptive geometry, thermodynamics, and FEM/FEA were not given much time, whereas the delphi group rated those subjects rather high. In each of these topics, typically viewed by educators as design engineering courses, industrial managers considered them more important than did educators. Interestingly, educators considered these same topics to be less important in the future. Industry's increased emphasis on the development of a closer-working relationship between design and manufacturing is apparent in the responses of the managers.

Materials is another area traditionally considered to be part of the design engineer's domain. However, the two groups only differed over the importance of the subject area. Furthermore, the groups only differed significantly over the importance of the introductory materials course. While Barnhart's (1988) study was considerably different, the curricula analysis he performed does suggest that educators perceived materials courses to be more important than did the delphi panel members. This study supports Barnhart's suggestion. However, careful analysis of the ANOVA data indicates that the two groups only differed significantly over the basic topic

areas. This may suggest that educators more readily identified the listed topics with specific courses, whereas, the managers may have several topics independently.

The next two hypotheses relate to manufacturing processes, systems, and automation. These are subject areas in which the two groups should agree. However, they differed significantly over the importance of both subject areas and over the future importance of manufacturing systems and automation. Again, educators perceived the basic manufacturing processes course to be more important than did the managers. The educators are very familar with the terminology used in the description of the topic and may have perceived the content differently. The two groups also differed significantly over the importance of the "high tech" topic areas in the manufacturing systems and automations. Educators rated the topics considerably higher in importance than did managers. This is consistent with the perception discovered by Foston (1984) and the Curricula 2000 (SME, 1990a) study.

Educators and managers did not differ over the controls subject area in any of the categories. This appears to differ with the findings of Barnhart (1988). Barnhart noted that the delphi panel rated vison adaptive controls and control systems very high, while his analysis of institutional curricula did not include much time for such topics. However, the topic areas in this were described using more traditional control terminology. If the controls subject area included "vision adaptive controls," it is very likely that the two groups would have differed, considering the tendency for educators to inflate their responses when "high tech" terminology is used.

The two groups differed significantly over all three categories pertaining to manufacturing management, productivity, and quality. Clearly, the

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managers were more sensitive to the topics in these categories. Given their daily involvement with most of the topic areas listed within the subject area, it is not surprising that the managers rated several topics considerably higher in importance and in future importance than did educators. Furthermore, the managers preferred more practical levels of instruction that did the educators. In a broader sense, this supports Barnhart's (1988) findings. The curricula he analyzed did not allocate much time for personnel topics. However, the delphi panel ranked the importance of personnel management very high.

Interestingly, the two groups did not differ over the importance or the level of instruction needed for computer applications within the curriculum. They did differ over the future importance of computer applications. Managers perceived traditional engineering languages equally as important as the new languages. Educators rated the future importance of fortran and BASIC very low and "C" programming very high. Furthermore, both groups rated word processing and spreadsheet topics very high. This is in agreement with Barnhart's study.

Finally, the two groups differed over the importance and the level of instruction needed for the three types of capstone topics identified. Educators preferred the traditional "individual" or "within discipline" experiences, while the managers perceived the "outside of discipline" experience to be most important. The emphasis on integration between disciplines is greater in industry and more visible than within the academic community. The significant difference between the two groups regarding the importance and the level of instruction needed for the "out of discipline" experience is supported by Kelly's (1987) findings.

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Many of the comments written by the respondents were similar to the criticisms identified in the review of the literature. While there were several industrial managers who suggested that a more practical curriculum would serve the graduate better (which parallels the comments of many of the industrial leaders cited in the review of the literature), overall, the two groups did not differ significantly with respect to the level of instruction needed in very many subject areas. Many of the educators called for an expanded curriculum (five years) to accommodate the additional subject areas. Several respondents from both groups called for less technical specialization and more broader experiences within the curriculum. This is in agreement with the comments of participants in the Koska and Romano (1988) study. There were also several comments which urged both groups to work together to develop a curriculum which would benefit the discipline.

Conclusions and Recommendations

Do manufacturing engineering technology educators and industrial manufacturing managers differ in respect to issues of curriculum? Clearly, as these data show, they differ significantly in many subject areas. This analysis revealed that manufacturing managers and manufacturing engineering technology educators differed in their views of manufacturing engineering technology curriculum issues in 16 out of 33, or 48.5 per cent, of the cases. Furthermore, the differences are significant in subject areas where agreement should exist. If the liberal studies subject areas are removed from the data, the educators and managers differed in respect to the importance of

75 per cent of the subject areas directly related to manufacturing. They also differed over the future importance of 50 per cent of these subject areas. Broad assumptions also confirmed in this study include: there is a bias toward metal working by manufacturing educators; there is a tendency for educators to exaggerate the importance of "device-oriented" subjects; manufacturing managers prefer graduates with broad manufacturing competencies over graduates with narrow, technical competencies; issues relating to manufacturing management, productivity and quality are significantly more important to the manufacturing manager than they are to the educator; and there is a clear preference on the part of managers for more interdisciplinary activities within the curriculum. The study did not confirm that the manufacturing engineering technology curriculum is too theoretical.

The Curricula 2000 (SME 1990a) study and the Barnhart (1988) study observed that the course materials they reviewed showed a bias toward metal working. Barnhart noted that the industrial participants in delphi panel in his study did not share that bias. This study confirms Barnhart's observation and the assessment of the Curricula 2000 study group -- educators rated those subject areas as being more important and remaining more important in the future than did the manufacturing managers. Educators should consider reducing the traditional emphasis on metal working in the curriculum while increasing the content of other aspects of manufacturing.

A portion of this study appears to support the tendency observed by Charles Carter (SME, 1990a). Carter observed that educators are often too "device-oriented" in their coursework. The significant difference between the two groups in respect to the importance of manufacturing processes and manufacturing systems and automations subject areas can be traced to the



higher rating the educators gave the "device-oriented" topics. However, unlike the *Curricula 2000* study (which Carter was analyzing), both groups did not rate the importance of the controls subject area unusually high. Further, they did not differ in respect to the three categories.

This study does not confirm the often repeated criticism of industrial observers that the curriculum is too theoretical. The industrial participants in the Koska and Romano (1988) study recommended a more practically-oriented curriculum addressing the needs of industry. This study suggests that educators, at least in the manufacturing engineering technology curriculum, agree. In fact, of the four areas in which the two groups differed in respect to the level of instruction needed, educators were more likely to prefer a more practical approach than managers. Only in respect to manufacturing management, productivity and quality, did the managers suggest a more practical level of instruction than did the educators. These findings suggest that the industrial managers' perception may be unfounded. However, educators may be responding to what they would prefer, not to what is really happening within the curriculum. The Barnhart (1988), Taraman (1988), SME (1990,a), and McCluckie (1987) studies, which reviewed the actual curricula materials, suggest the curriculum is too theoretical. Thus, this study may merely reflect the perceptions of educators, not reality.

Particularly significant in this study are the higher ratings given by managers to the importance and the future importance of management topics and team activities outside of the discipline. The manufacturing engineer of the future, characterized in the Koska and Romano (1988) study as broader, more team-oriented, less scientific and mathematical, more management and business-oriented, with the ability to function in multi-disciplinary teams.



may already be reflected in the responses of the managers in these subjects. Managers placed significantly higher value on each of these subject areas than did educators. Thus, educators should consider advancing elements within the curriculum which offer students the opportunity to function with students from other disciplines.

All forms of engineering education originated from a very focused. object-based, task-oriented perspective -- engineers work with things for people, not with people. Only in recent years has it become evident that engineers must function as part of a total team to accomplish this objective effectively. To address this change, educators developed capstone projects in which students within the curriculum worked together to solve an engineering problem. These "team-building" activities are helpful, but they fail to address industry's problem -- securing graduates that can function effectively within a multidisciplinary team. Several institutions have created interdisciplinary or cross-disciplinary programs; however, students are not required to work together to solve a problem, they merely take courses together. This is commonly referred to as "interfacing" rather than "integrating." The capstone experience represents the ideal forum for students from all disciplines, typically found within a manufacturing enterprise, to work together to solve a problem. The noticeably higher ratings the managers gave the "team project out of discipline" and the "interpersonal skills" topic within the communications subject area, reflect this sentiment. Managers are looking for graduates who understand the broader ramifications of their work. Until the curriculum is changed to address and develop those competencies, these differences will remain.

Some of the differences between the two groups, exposed in this



study, can be attributed to a lack of understanding about what really is happening in "industry," or in the "university classroom." Only through an increase in the involvement of industrial manufacturing experts in the curriculum development process will both groups benefit. Historically, industrial experts who became involved with curriculum development, argued for a narrowly focused, technically in-depth program. Recent studies, including this research, suggest that now it is the industrial community, not the educators, who are advocating the development of a broader curriculum. Now is the time for each program to convene an industrial advisory board to review and examine the curriculum.

Further Research

Future studies addressing these questions would be useful:

- 1. Would practicing manufacturing engineers compare similarly to the responses of manufacturing managers?
- 2. Would the results vary significantly if the groups were divided according to geographic region or type of manufacturer?
- 3. What changes might take place if these two groups were studied in five years?
- 4. How much influence do industrial experts have on the development and/or revision of curriculum?

Reflections

Are the differences between manufacturing engineering technology educators and manufacturing managers, in respect to issues of curriculum,



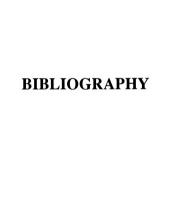
an indicator of one of the problems which brought about the demise of manufacturing in the United States? Perhaps, the rapidly changing manufacturing world has rendered much of the existing manufacturing-related engineering programs obsolete. Obviously, if manufacturing firms had been able to secure highly motivated, appropriately educated, young manufacturing graduates, they would have been more competitive. Few people appreciate what impact a well-prepared and motivated workforce would have on the competitiveness of the U.S.

Modern manufacturing requires different competencies than the current curriculum provides. Because educators have been slow to embrace
needed changes, it must be assumed that they either do not understand the
needed changes or they do not perceive the urgency to make such changes.
This study should promote such an understanding. At no time in the history
of our nation has the education of manufacturing professionals been more
critical. Thus, it was encouraging that a large majority of the educators participating in this study requested a copy of the results.

It is also important that changes be made quickly. As the opening remark cited in the Koska and Romano (1988) study suggests,

The 21st century is only about 4,000 days away [3,200 at the time of this study], a very short time for change. We (manufacturing engineers) are not ready. Most of us prefer isolation over integration, hardware over humans. We must wake up to change -- change our orientation to our work, our role, and most importantly our attitude, if we are to capitalize on the opportunities before us. Working with and through people is the key to our future success.

If this country is to become globally competitive, educators must be intricately involved in the needed changes. There is no alternative.



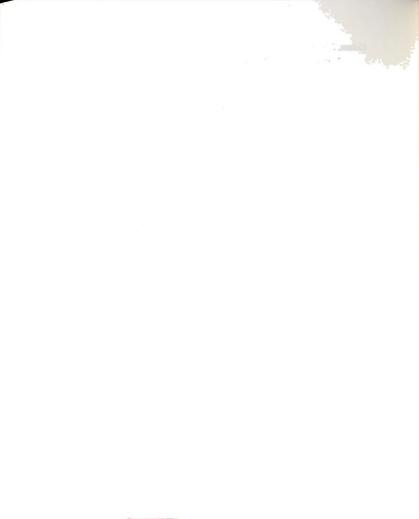


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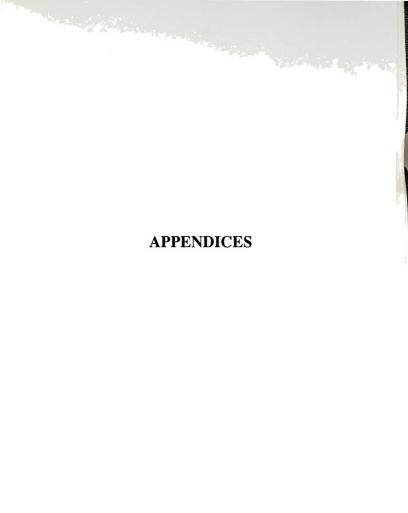
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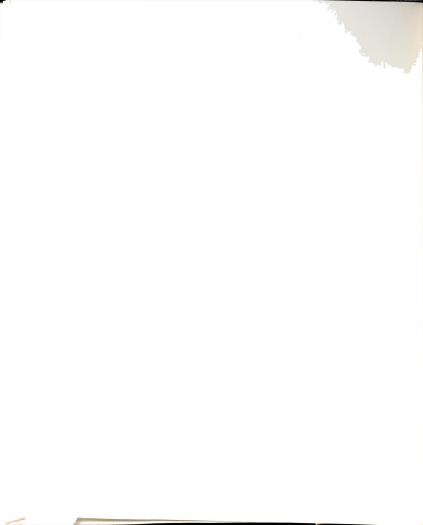
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APPENDIX A

Industrial Manufacturing Managers

Questionnaire





MANUFACTURING ENGINEERING TECHNOLOGY

A Nationwide Survey Comparing Industrial Manufacturing Managers and Manufacturing Engineering Technology Faculty



MANUFACTURING ENGINEERING TECHNOLOGY

This survey is being conducted to investigate and quantify the level of agreement between industrial manufacturing managers and faculty in manufacturing engineering technology programs regarding curriculum issues. Please respond to all of the questions. If you wish to comment on any questions or qualify your answers, please feel free to use the space in the margins. Your comments will be read and taken into account.

Thank you for your help.

Manufacturing Engineering Technologies Dept Ferris State University Big Rapids, Michigan 49307



BS Manufacturing Engineering Technology Curriculum Survey

Manufacturing Engineering Technologists work in that part of the manufacturing field which requires the application of scientific and engineering flowing edge and methods combined with the technical skills in support of manufacturing engineering activities; it lies in the occupational spectrum between the craftsman and the engineer at the end of the spectrum closest to the engineer.

Please circle the numbers which correspond to your perception of	10	51	FT	ECT	Z		NST	EVI OF RUG EED	cm	ON	D		TU	RE	CE
what a manufacturing engineering technologist needs.	5	ORTANCE	BLY 150		DAPORTANT	1.1	PORY	2017	ACTICAL	OMLY		S SOME	E SAME	INCREASE	
I. SCIENCE AND MATHEMATICS	UNIMPORTANT	LITTLE IMPORTANCE	MODERATERLY	IMPORTANT	VERY IMP	THEORY ONLY	MOSTLY THEOR	EQUAL BALANCE	MOSTLY PRACTIC	PRACTICAL ONLY	DECREASIN	DECREASING	ABOUT THE SAME	SOME INC	INCREASIN
Algebra and Trigonometry	1	2	3	4	5	1	_	-		5	1	_	-	4	٦
2. Calculus I	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
3. Calculus II	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
mechanics and heat		2	3	4	5	1	2	3	4	5	1	2	3	4	5
5. Physics II	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
6. Chemistry laws and theories of general chemistry	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
II. COMMUNICATIONS															1
1. Formal Public Speaking	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
2. Technical Presentations	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
3. Technical Reports	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
4. Interpersonal/Team Skills	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5



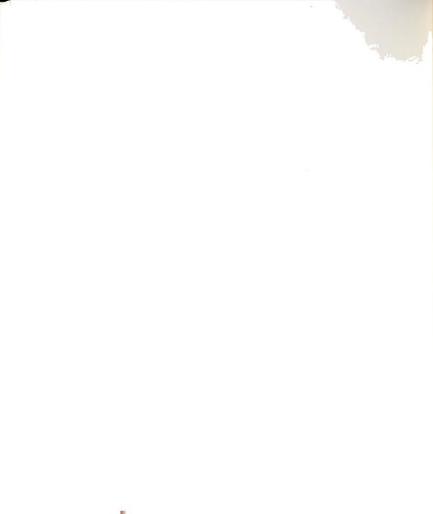
	Please circle the numbers which correspond to your perception of what a manufacturing engineering technologist needs.			OF UB	TAN THE JECT EA		IN	STI	OF RUC ED	TIC	N	IN	FU MPC		AN	
	what a manufacturing engineering		RTANCE	Y IMP		TANT		DRY	NCE	CTICAL	NLY		SOME	SAME	ASE	
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1.	Global Awareness	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
2.	Social Awareness	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
3.	Cultural Appreciation	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
4.	Ethical & Value Sensitivity	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
v.	DESIGN FOR PRODUCTION															
1.	Elementary Engr Graphics orthographic proj, dimensioning, sectioning, pictorials	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
2.	Descriptive Geometry normal, inclined, oblique surfaces in space	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
3.	Two-Dimensional CADD create, edit, manipulate and dimension 2D CAD geometry	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
4.	Design Layout	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
5.	Geom Dim and Tolerancing GD&T to control design functionality	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
6.	Product Design	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
7.	Three-D CAD with Surfacing 3D wire frame, complex surfaces, B-	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
8.	splines, NURBS	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5



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Please circle the numbers which correspond to your perception of what a manufacturing engineering technologist needs.	UNIMPORTANT	LITTLE IMPORTANCE	MODERATERLY IMP	DAPORTANT	VERY IMPORTANT	THEORY ONLY	MOSTLY THEORY	EQUAL BALANCE	MOSTLY PRACTICAL	PRACTICAL ONLY	DECREASING	DECREASING SOME	ABOUT THE SAME	SOME INCREASE	
9. Kinematics	1	2	3	4	5	1	2	3	4	5	1	2	3	4	:
10. Dynamics	1	2	3	4	5	1	2	3	4	5	1	2	3	4	
11. Statics/Strength of Mat'ls force systems, moments of inertia, shear & moment diagrams, stresses	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
12. Thermodynamics	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
13. Design of Machine Elements shafts, bearings, brakes, gears, cams, springs, screws, machine elements	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
14. Design for Manufacturability impact of major manufacturing processes on design	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
15. Manufacturing Tooling Design dies, molds, fixtures, jigs	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
. MATERIALS					1										
Intro to Engr Mat'ls	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
2. Non-destructive Testing dye penetrants, magnetic, ultrasonic radiography	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5



Please circle the numbers which	I	S)FT	ECT		n	√STI	EVI OF RUC	TIC	ON	n	FUMPO		IRE	
correspond to your perception of what a manufacturing engineering technologist needs.	UNIMPORTANT	TITLE IMPORTANCE	HODERATERLY IMP	MPORTANT	VERY IMPORTANT	THEORY ONLY	MOSTLY THEORY	EQUAL BALANCE	MOSTLY PRACTICAL	PRACTICAL ONLY	DECREASING	DECREASING SOME	ABOUT THE SAME	SOME INCREASE	INCREASING
3. Physical Metallurgy	1	2	3	4	5	1	2	3	4	5	1	2	3	4	-5
properties of metals, alloys, carbon steels, failure analysis 4. Selection of Materials case studies, mat'l selection, optimal mat'l for application	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
5. Polymer Materials	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
6. Polymeric Composites base resins, fiber mat'ls, addititives, mech properties	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
VI. MANUFACTURING PROCESSES															
Basic Manuf Processes conventional machining, casting, finishing, joining, inspection, metrology, presses	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Conventional Machining	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
3. Fabrication and Pressworking fasteners, sheet metal, welding, SMAW, GMAW, GTAW resistance welding, pressworking	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
4. Casting Operations	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
5. Electronics Fabrication	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5



Please circle the numbers which			OF UB,	TAI TIII JEC IEA		п	NST	EVI OF RUG EED	CTIC	ON	n	FUMPO		IRE	
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6. Plastics injection, blow, extrusion, rotational, tooling, materials 7. Nontradional Mat'l Removal EDM, ECM, laser machining, water jet cutting, plasma, ultrasonic, ion beam	1	2		4	5	1	2	3	4	5	1	2	3	4	5
VII. MANUFACTURING SYSTEMS AND AUTOMATION															
Expert Systems	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Metrology	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
3. Statistical Process Control reliability, measurement, control, sampling, statistical design of quality systems	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
4. Group Technology coding and classifying of parts according to similarities	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
5. Computer Aided Process Planning computer assistance with the production planning process	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
6. Manufacturing Resource Plan scheduling of mai's, equipment, personnel, JIT	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
7. Computer Aided Manufacturing tool path generation over CAD models, transfering tool path	1		3	4	5	1	2	3	4	5	1	2	3 .	4	5

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Please circle the numbers which correspond to your perception of what a manufacturing engineering technologist needs.	IMIMPORTANT	LITTLE IMPORTANCE	MODERATERIA IMP	MPORTANT	VERY IMPORTANT	THEORY ONLY	MOSTLY THEORY	EQUAL BALANCE	MOSTLY PRACTICAL	PRACTICAL ONLY	DECREASING	DECREASING SOME	ABOUT THE SAME	SOME INCREASE	INCREASING
8. Manufacturing Simulation computer simulation of material flow, FMS, manufacutring processes or systems	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
9. Design for Assembly computer assisted design analysis for optimal assy	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
11. Automated Material Handling robots, AGV's, automated mat'l handling devices	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
12. Automated Data Collection sensors, bar code readers, probing devices	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
14. PLC Operations and Prog	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
15. Automations Sensors contact/noncontact switches, vision, proximity, optical	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
16. Systems Integration LAN's, MAP, TOP, IGES, PDES, interfacing systems, protocol	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
17. Computer Integrated Manuf design and setup an integrated manufacturing system	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5

Page 6



IMPORTANCE OF THE SUBJECT

AREA

LEVEL OF INSTRUCTION NEEDED

FUTURE IMPORTANCE

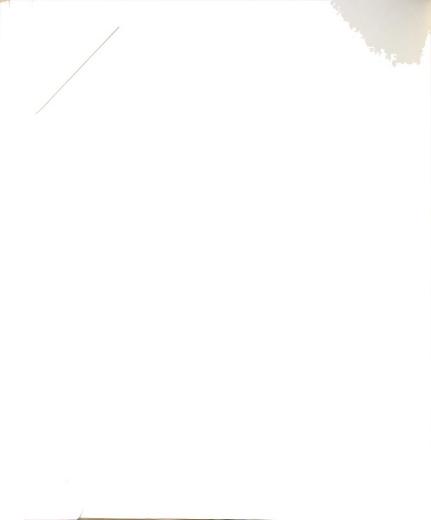
Please circle the numbers which correspond to your perception of what a manufacturing engineering technologist needs.

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VIII. CONTROLS	THOMPSON		TA STORY	MEDITAN	VERY IMP	THEORYO	MOSTLYTI	EQUAL BA	MOSTLY P	PRACTICAL	DECREASIN	DECREASIN	ABOUT TH	SOME INC	INCREASIN
Electrical/Electr Controls ACIDC circuits, ladder logic, solid state devices, PLC's,	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
transducers, detectors 2. Fluid Power hydraulic/pneumatic circuits, fluid properties, component selection	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
3. Control of Indust Automation automated systems, comp assisted logic diagrams, binary logic, boolean algebra, moving logic	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
IX. MANUFACTURING MANAGEMENT, PRODUCTIVITY AND QUALITY															
Business Management	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Motion and Time Study	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
3. Process Planning and Design process planning for low, medium and high volumes to a target cost	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5



Please circle the numbers which			OF	TAN FHE IECT		n	ST	EVI OF RUC	CTI	ON	n	FUTURE IMPORTANCE			
correspond to your perception of what a manufacturing engineering technologist needs.	THE PROPERTY OF	THE IMPORTANCE	MODERATE NAMED	MODELANT	VERY IMPORTANT	THEORY ONLY	MOSTLY THEORY	EQUAL BALANCE	MOSTLY PRACTICAL	PRACTICAL ONLY	DECREASING	DECREASING SOME	ABOUT THE SAME	SOME INCREASE	INCREASING
6. Quality in Manufacturing capability studies, control charts sampling plans, design of experiments, tool and gauge	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
controls, auditing, FMEA 7. Organizational Behavior organizational design, leadership, teamwork, project management	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
8. Engineering Economics	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
X. COMPUTER APPLICATIONS															
1. BASIC Programming	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
2. Fortran Programming		2	3	4	5	1	2	3	4	5	1	2	3	4	5
3. "C" Programmming	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
4. Wordprocessing Software	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
5. Spreadsheet Software	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
6. Database Software	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
7. System Selection and Evaluation	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
XI. CAPSTONE EXPERIENCE															
1. Individual Project	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
2. Team Project within Discipline	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
3. Team Project with other Disciplines	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5



Part II		
Demographic	Data	

	Demographi	c Data
. In wh	ich industry do you work	(SIC)?
	Metal Products (3-	40)
	Machinery (350)	
	Electrical (360)	
	Transportation (37	70)
	Instruments (380)	
. How r	nany employees are there	in your company?
	1 - 19	
	20 - 99	
	100 - 299	
	300 - 499	
	500 - 999	
	Over 1000	
		ple (at all levels) who work under dministrative supervision?
	None	
	1 - 5	
	(10	
	11 - 25	
	26 - 100	
	Over 100	
Whati	Over 100	oldraining if any?
What i		al training, if any?
	Over 100	4 year BS Mfg Engr Tech
2	Over 100	
2	Over 100	4 year BS Mfg Engr Tech
2 4	Over 100	4 year BS Mfg Engr Tech 4 year BS Engr



Is there anything else you would like to tell us about the ideal BS Manufacturing Engineering Technology curriculum? If so, please use this space for purpose.

Your participation in this effort is greatly appreciated. If you are interested in a summary of the results, please print your name and return address on the return envelope (NOT on this questionaire).



You Have Completed the Survey THANK YOU

Please insert into the return envelope and mail

Manufacturing Engineering Technologies Department Ferris State University Big Rapids, Michigan 49307



APPENDIX B

Manufacturing Engineering Technology Faculty
Questionnaire
Part II Demographic Data



Part II Demographic Data

Ye	No
2. How man	ny graduates/year does your program produce?
	1-9
	10 - 19
	21 - 29
	30 - 49
	50 and Over
3. What is	your terminal degree?
	AAS
	BS
	MS
	Ed
	Phd
	Other
4. How man	ny years of industrial experience do you have?
	1 - 5 years
	6 - 10 years
	11 - 15 years
	Over 16 years



APPENDIX C

Industrial Manufacturing Managers

Questionnaire Cover Letter



John/Jane Dole (Industrial Manager) 1234 Short Road Anytown, USA

Concerns about U.S. competitiveness in a global environment are increasing daily. Those concerns have been accompanied by an increase in the criticism of manufacturing-related programs in higher education. Typically, the criticism focuses on curriculum issues: "every manufacturing engineer should have a course in QFD," or "why don't your students have more 'hands-on' experience with CMM's?" Only a few years ago, both of these topics were unimportant. Today, the process of revising a manufacturing-related curriculum has become a process of elimination. Which subjects are more important? Will students really need to do some lab work in this course? Will this subject be more or less important in the future?

In addition to this dilemma, faculty in manufacturing-related fields are often unaware of how they differ with industrial managers who hire their graduates in respect to curriculum matters. Understanding the importance of a subject area, or the level of instruction needed, is especially important to faculty involved with BS Manufacturing Engineering Technology programs—programs designed to prepare graduates for immediate functionality.

You are one of a small number of manufacturing engineering managers being asked to give their opinion on these matters. You were selected randomly from a list of industrial manufacturing managers working in the United States. In order that the results will truly represent the thinking of the manufacturing engineering managers in the U.S., it is important that each questionnaire be completed and returned. The questionnaire should take less than 15 minutes for you to complete.

You may be assured of complete confidentiality. The questionnaire has an identification number for mailing purpose only. This is so that we may check your name off the mailing list when your questionnaire is returned. Your name will never be placed on the questionnaire. By returning the questionnaire, you will indicate your willingness to participate in this study.

You may receive a summary of the results by writing "copy of the results requested" on the back of the return envelope and printing your name and address below it. Please do not put this information on the questionnaire. I would be most happy to answer any questions you might have. Please write or call (616) 592-2511. Thank you for your assistance.

Sincerely,

Ray Cross Head, Manufacturing Engineeriong Technologies Department

Students

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APPENDIX D

Manufacturing Engineering Technology Faculty Questionnaire Cover Letter



John/Jane Doe (Faculty Member) 1234 Short Road Anytown, USA

Concerns about U.S. competitiveness in a global environment are increasing daily. Those concerns have been accompanied by an increase in the criticism of manufacturing-related programs in higher education. Typically, the criticism focuses on curriculum sincess: "every manufacturing engineer should have a course in QFD," or "why don't your students have more 'hands-on' experience with CMM's?" Only a few years ago, both of these topics were unimportant. Today, the process of revising a manufacturing-related curriculum has become a process of elimination. Which subjects are more important? Will students really need to do some lab work in this course? Will this subject be more or less important in the future?

In addition to this dilemma, faculty in manufacturing-related fields are often unaware of how they differ with industrial managers who hire their graduates in respect to curriculum matters. Understanding the importance of a subject area, or the level of instruction needed, is especially important to faculty involved with BS Manufacturing Engineering Technology programs—programs designed to prepare graduates for immediate functionality.

You are one of a small number of manufacturing engineering technology faculty being asked to give their opinion on these matters. You were selected from the list of faculty and administrators associated with BS manufacturing engineering technology programs in the SME "Directory of Manufacturing Education." In order that the results will truly represent the thinking of the manufacturing engineering technology faculty in the U.S., it is important that each questionnaire be completed and returned. The questionnaire should take less than 15 minutes to complete.

You may be assured of complete confidentiality. The questionnaire has an identification number for mailing purpose only. This is so that we may check your name off the mailing list when your questionnaire is returned. Your name will never be placed on the questionnaire. By returning this questionnaire, you indicate your voluntary agreement to participate in this study.

You may receive a summary of the results by writing "Copy of the Results Requested" on the back of the return envelope and printing your name and address below it. Please do not put this information on the questionnaire. I would be most happy to answer any questions you might have. Please write or call (616) 592-2511. Thank you for your assistance.

Sincerely,

Ray Cross

Head, Manufacturing Engineering Technologies Department

APPENDIX E

Request for Study Endorsement Society of Manufacturing Engineers



November 26, 1990

Mr. Gary J. Peterson, CMfg, P.E., President Society of Manufacturing Engineers One SME Drive P.O. Box 930 Dearborn. MI 48121-0930

Dear Mr. Peterson:

The purpose of this letter is to request your support of a research study I am conducting as part of a doctoral program at Michigan State University. For that study, I need your help in two areas: 1) securing 500 mailing labels from SME of manufacturing engineering managers, and 2) a brief letter from you which could be copied and mailed to the survey participants endorsing the research and encouraging their cooperation.

Enclosed is a "draft" of the survey instrument which will be mailed to 500 industrial manufacturing managers and approximately 60 manufacturing engineering technology faculty in the United States. The purpose of the research is to determine if industrial manufacturing managers and faculty of manufacturing engineering technology BS programs differ in respect to the importance, the desired level of instruction, and the future importance of the curriculum subject areas identified in the Curricula 2000 report.

Where there are significant differences, changes in curriculum can be targeted for greater emphasis and attention. This research will serve that purpose. I expect to publish the research results in an SME educational report and present the findings at an SME technical conference. Furthermore, this information would be made available to the SME educational committee.

Your endorsement and support of this research, even in a partial manner, will greatly increase the response rate, improve the validity and reliability of the study, and enhance the credibility of the study. If you have any questions, I can be reached at (616) 592-2511.

Sincerely,

Ray Cross, Head Manufacturing Engineering Technologies Department (Senior Member 3310026)

Enclosure

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APPENDIX F

Request for Study Endorsement Ferris State University



Ferris State University

TO: Joel Galloway, Dean College of Technology

FROM: Ray Cross, Head MFG Engr Tech Department

SUBJECT: Institutional Support For Research Study

DATE: November 26, 1990

Attached is a copy of my dissertation research proposal titled, "A COMPARISON OF MANUFACTURING ENGINEERING TECHNOLOGY FACULTY AND MANUFACTURING MANAGERS ON ISSUES OF CURRICULUM: CURRENT SUBJECT AREA IMPORTANCE, DESIRED LEVEL OF INSTRUCTION, AND FUTURE IMPORTANCE OF SUBJECT AREAS." This study will directly impact the BS Manufacturing Engineering Technology program in my department. Therefore, I am requesting institutional endorsement and support for this research in the form of:

- permission to use Ferris State University letterhead stationery and envelopes for all mailings,
- permission to use the copy center facilities for this research project,
- permission to use the library facilities for searches associated with this project,
- permission to use the IBM mainframe and the SPSS-X statistical software package for data analysis during this research project, and
- permission to use institutional mailing privileges for this project where necessary.

Thank you for the support you have already extended to me during my quest to complete this degree.



APPENDIX G

Approval of the University Committee on Research Involving Human Subjects



MICHIGAN STATE UNIVERSITY

OFFICE OF VICE PRESIDENT FOR RESEARCH

EAST LANSING . MICHIGAN . 48824-1046

December 17, 1990

Mr. Ray Cross 5667 N. Elm Big Rapids, MI 49307

RE: A COMPARISON OF MANUFACTURING PROLINEERING TECHNOLOGY FACULTY AND MANUFACTURING MANAGERS ON ISSUES OF CURRECULLHY. CURRENT SUBJECT AREA IMPORTANCE, DESIRED LEVEL OF INSTRUCTION, AND FUTURE IMPORTANCE OF SUBJECT AREAS.

Dear Mr. Cross:

The above project is exempt from full UGRIHS review. The proposed research protocol has been reviewed by another committee member. The rights and welfare of human subjects appear to be protected and you have approval to conduct the research.

You are reminded that UCRIHS approval is valid for one calendar year. If you plan to continue this project beyond one year, please make provisions for obtaining appropriate UCRIHS approval one month prior to December 11, 1991.

Any changes in procedures involving human subjects must be reviewed by UCRIHS prior to infitation of the change. UCRIHS must also be notified promptly of any problems (unexpected side effects, complaints, etc.) involving human subjects during the course of the work.

Thank you for bringing this project to my attention. If I can be of any future help, please do not hesitate to let me know.

Sincerely,

David E. Wright Ph.D. Chair, UCRIHS

DEW/deo

cc: Dr. Eldon Nonnamaker

