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An analysis of manufacturing facility characteristics and four-year manufacturing engineering technology competencies for ABET accredited programs in North Carolina

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AN ANALYSIS OF MANUFACTURING FACILITY CHARACTERISTICS AND FOUR-YEAR MANUFACTURING ENGINEERING TECHNOLOGY COMPETENCIES FOR ABET ACCREDITED PROGRAMS IN NORTH CAROLINA

A Dissertation

Submitted

in Partial Fulfillment

of the Requirements for the Degree

Doctor of Industrial Technology

Approved:

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Dr. John Fecik,	Co-Chair
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ABSTRACT

The purpose of this study was to determine the degree of correlation between four-year ABET/MET competencies and company demographics of plant location and plant size and usage of manufacturing technologies, and to determine the overall rating per SIC classification of validated MET competencies. This purpose is reflective of the literature, which indicated that there is a need for further development of manufacturing engineering technology competencies to meet the industry needs of a region or state.

A questionnaire was used to collect data. It was mailed to 440 randomly selected practicing manufacturing engineers in North Carolina. The sample size was 50. The study had a response rate of 11.4%. One hundred thirty-seven MET competencies were dependent variables. Independent variables were number of employees at the work site, utilization of a spectrum of manufacturing technologies, and plant location.

Data were analyzed using Microsoft Excel and Windows SPSS and the level of significance was set at .05. Four procedures were used to analyze the data: (a) linear regression (F-ratios, r-square, beta coefficients, t-test); (b) Pearson's correlation; (c) point biserial correlation; and (d) descriptive statistics.

Significant correlation existed between plant size large and competency category 3-Manufacturing Processes, and between plant size grouped data and competency category 5,-Controls. These were the only two tail independent variables which had significant correlation and t-test statistics, indicating their association with the perceptions of respondents regarding important MET competencies. Competencies 3,5,7, and 8 (Manufacturing Processes, Controls, Liberal Studies, and Capstone Courses) had significant one tail directional correlation with grouped plant size data. One tail directional correlation existed between competency 3-Manufacturing Processes and medium plant size, and between competency 3-Manufacturing Processes and large plant size.

Five percent of the 137 entry-level MET competencies were considered as "extremely important" by manufacturing engineers, 67% were considered "very important," 27% as "important," and the remaining odd percentages as "minimally" and "not important." The 137 competencies are grouped into major heading categories. Respondents were asked to rate the importance of competencies on a 1-5 scale. The overall competency category ranked importance from rated competencies are from highest to lowest (1) Capstone Courses, (2) Design for Production, (3) Liberal Studies, (4) Manufacturing Management/Quality Productivity, (5) Manufacturing Processes, (6) Manufacturing Systems and Automation, (7) Control, and (8) Materials.

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CHAPTER I

INTRODUCTION

Nature of the Problem

Engineering Technology is an academic discipline that contains areas of specialization in particular fields. One of these fields of specialization is Manufacturing Engineering Technology (MET; Edwards, 1984). The rapid growth of global competition, new manufacturing technologies, changes in plant demographics, and an educational shift toward industrial-education cooperation and partnerships during the last 15 years has generated an increased need for educators to examine their manufacturing curricula to determine if college graduates are being prepared to meet the needs of their local, regional, and state industries.

Previous research has established a validated set of Manufacturing Engineering Technology competencies required of entry-level graduates but failed to address the industrial education needs according to the demographic needs of industry. Industrial characteristics, utilization of modern manufacturing technology, and management methods are not constant across industry type, location and organizational structure. The scope of manufacturing education reaches beyond the classroom and into the local and regional needs of industry. To better understand the affect of manufacturing variables on MET competencies and to better equip manufacturing educators on curricula content specific to their service areas, this study will identify relationships between characteristics of manufacturing facilities and established competencies for MET programs in the state of North Carolina.

Statement of the Problem

The problem of this study is to determine the ranked importance of previously validated four-year ABET/MET competencies based on the rated response of industrial representatives and to determine the degree of correlation between MET competencies and manufacturing facility characteristics delineated according to usage of manufacturing technology, plant location, and plant size.

Statement of Purpose

The purpose of this study is to assist North Carolina manufacturing educators involved with curriculum development, workforce development, and technology transfer by identifying competency priorities according to generalized manufacturing characteristics and demographics.

Significance of the Study

The significance of this study arises from increased focus on regional economic development and divergent industrial characteristics.

Education's Role in Regional Economic Development

The need for determining the effect of manufacturing facility characteristics on MET competencies is evident by changing economic factors in manufacturing and by the growing perceived responsibility of universities to engage higher education in the economics of community and regional development.

Ferro (1993) in a study sponsored by the American Association of State Colleges and Universities presents a model for college and university participation in economic community development. The model suggests steps for institutional self-assessment and participation in economic development. These steps include (a) developing a planning process that involves bringing together key institutional and community decision makers, (b) identify problems faced by educators as they attempt to expand their leadership role in economic and community development planning, (c) analysis of the institutions' environment, and (d) development of goals and strategies for economic participation. A total of eight colleges and universities utilized the model, including Western Carolina University. Smith (1996), in a study to determine the quantitative relationships between colleges and the economic development of the communities in which they were located, found that there is value of post-secondary education for economic development. There are direct linkages between manufacturing jobs and earnings and occupational enrollment. The engagement of universities into the economic success of businesses and industries requires an examination of the specific competencies required of graduates for those businesses.

Divergent Industrial Characteristics

The University of North Carolina System is composed of 16 universities. Two of these universities offer MET baccalaureate degrees, The University of North Carolina at Charlotte (UNCC) and Western Carolina University (WCU; ABET, 1998). The 1997 mission statement at WCU states "As a major public resource for Western North Carolina, the University assists individuals and agencies in the region through the expertise of its faculty, its staff, and its students" (WCU, 1999 p. 23). McClure (1997) stressed a ". . . need to increase contact with industry and work world--especially with changing economy of WNC from basic production to competitive/high tech new industries" (p. 16). As a result of this increased need of business and manufacturing education, and technology transfer, the Chancellor at WCU initiated funding for a Regional Technology Center on the WCU campus (McClure, 1997). The mission of UNCC reads,

> To provide for the educational, economic, social, and cultural advancement of the people of North Carolina through on and off campus programs, continuing personal and professional education opportunities, research, and collaborative relationships with the private, public, and nonprofit institutional resources of the greater Charlotte metropolitan region. (UNCC, 1999, p. 12)

Small to medium sized industries utilize varying degrees of modern manufacturing technologies and employee educational plans. Reddy (1993) indicated companies have not kept pace with international competitive practices, particularly small automotive suppliers that are in desperate need of upgrades yet are least able to afford them. Smaller companies have fewer resources to devote to plant modernization and employee training. Smaller manufacturing firms tend to have older technologies, require modernization and need manufacturing engineers and technicians equipped with competencies necessary to lead these upgrades. Chisman (1992) sampled 11,000 small businesses nationally to determine their workforce educational plans. Medium-sized industries tend to have more capital and can invest in employee education plans.

Small business programs tend to be low intensity, quick-fix types; few encourage lifelong learning. Employers who offer programs do so because of competition, a need to produce high quality products, and enlightened human resource policies.

Diverse industries and plant size are prevalent in North Carolina. According to the 1996 census there were 12,349 manufacturing industries. These plants employed a total of 861,525 workers. Fifty-nine percent of all manufacturing industries in North Carolina employ fewer than 19 employees (Office of State Planning, 1999).

Basic competencies for MET graduates are needed for U.S. participation in the global economy and are well documented. A study by the Society of Manufacturing Engineers (SME) supports the need for basic entry-level competencies of MET graduates and requires the development of certain competencies as criteria for grant funding (SME, 1998). How these basic competencies are developed can be influenced by the individual characteristics of manufacturing facility characteristics of a particular university service area. Should rural universities focus more on a particular group of competencies because small businesses are dominate the region? The influence of manufacturing facility characteristics on these basic competencies has not been investigated.

The findings of this study will be used as a foundation for developing curricula content for adult and continuing education programs in North Carolina. The study will serve as a basis for curriculum up-dating to enhance professional/technical preparation of MET graduates entering the manufacturing industry in North Carolina and serve as curricula model for similar rural and urban manufacturing environments throughout the U.S.

Research Questions

The following research questions are designed to address the needs of four-year MET/ABET programs in North Carolina. In each case the statistical null hypothesis is indicated.

1. Is there a significant relationship between the degree of usage of manufacturing technologies and each industrial desired competency category?

Hypothesis 1a

There is zero correlation between usage of manufacturing technology and each MET competency category in the population.

Hypothesis 1b

The independent variable usage of technology is not a significant variable in determining each competency importance.

Hypothesis 1c

There is zero correlation between usage of manufacturing technology and the overall importance of MET competencies (mean response of all competencies each plant) in the population.

Hypothesis 1d

The independent variable usage of technology is not a significant variable in determining the overall importance of MET competencies (mean response of all competencies each plant).

2. Is there a significant relationship between the number of employees at the work site (plant size) respondents and each desired competency category?

Hypothesis 2a

There is zero correlation between plant size grouping small, medium, and large and each MET competency category in the population.

Hypothesis 2b

The independent variables of small, medium, and large plant size are not significant variables in determining each competency category.

Hypothesis 2c

There is zero correlation between plant size and the overall importance of all MET competencies (mean response of all competencies each plant) in the population.

Hypothesis 2d

The independent variable of plant size is not a significant variable in determining the overall importance of all MET competencies (mean response of all competencies each plant).

Hypothesis 2e

There is zero correlation between plant size (all plant sizes grouped together) and each MET competency category in the population.

Hypothesis 2f

The independent variable plant size (all plant sizes grouped together)are not significant variables in determining the importance of each MET competency category.

3. Is there a significant relationship between plant location and each competency category?

Hypothesis 3a

There is zero correlation between plant location (urban/rural) and each MET competency category in the population.

Hypothesis 3b

There is not a significant relationship between plant location (urban/rural) and each MET competency category.

Hypothesis 3c

There is zero correlation between plant location and the overall importance of MET competencies.

Hypothesis 3d

The independent variable plant size is not a significant variable in determining the overall importance of MET competencies.

4. What is the overall perceived importance of each industrial desired competency?

5. What is the overall perceived importance of each industrial desired competency according to SIC groupings?

Operational Definitions

The following terms are defined to clarify their use in the context of the study:

1. ABET--Accreditation Board for Engineering and Technology. An accreditation body whose function is to provide world wide leadership to assure quality and stimulate innovation in engineering, technology, and applied science education (ABET, 1998, p. 1).

2. Competency--A predetermined set of knowledge, skills, and abilities that the student is expected to accomplish (Shafritz, 1988).

3. Competency Category--a group of similar competencies in function and purpose.

4. Engineer--one who applies science to the optimum conversion of the resources of nature to benefit humankind. Broad based principally on physics, chemistry, and mathematics. Engineering extends into material science, solid and fluid mechanics, thermodynamics, transfer and rate of processes, and systems analysis (Akinkuoye, 1991).

5. Engineering Technology--is that part of the 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

craftsperson and the engineer at the end of the spectrum closest to the engineer (ABET, 1998).

6. Entry-level Employment--employment, after graduation, in a professional position carrying duties and responsibilities proportionate with a baccalaureate or associate degree in manufacturing engineering technology.

7. Manufacturing Engineering Technology--very much a part of the definition of manufacturing engineering, it is that part of the 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 craftsman and the engineer at the end of the spectrum closest to the engineer (SME, 1987).

8. Manufacturing Technologist--an individual assigned to projects on design, development, and implementation of engineering plans; drafting and erecting manufacturing engineering equipment; estimating and inspection; maintaining manufacturing machinery or manufacturing services; assisting with research and development; sales and presentation; and servicing and testing of materials and components (Brummett, 1985).

9. Manufacturing Engineering--manufacturing engineering is that specialty of professional engineering

which requires such education and experience as is necessary to understand, apply and control engineering procedures in manufacturing process and methods of production of industrial commodities and products (Yost, 1984).

10. Company production profile--business, demographic, and manufacturing methods and technologies that contribute to the production of products.

11. Perception--"a mental awareness or cognizance of relationships between work responsibilities and necessary traits or competencies to carry out those responsibilities" (Brown, 1983, p. 17).

12. Rural--communities with fewer than 2500 inhabitants or land mass containing fewer than 1000 inhabitants per square mile (Herzog, 1996).

13. Statistics--a set of procedures for describing, synthesizing, analyzing, and interpreting quantitative data (Gay, 1992, p. 371).

14. Technician--assists in the practical aspects of coordinating the skills of the craftsperson, and sometimes responsible for building and maintaining industries and operating systems with the assistance of craftsperson (Akinkuoye, 1991).

15. Variable--a differing element of a sample (Guralnik, 1984).

16. Standard Industrial Classification (SIC)--a numerical code which identifies one specific industrial product or product line. The first two digits represent a broad class of product, such as machinery (SIC 35). The final two digits of the four-digit code delimit the class of product, such as food products machinery (SIC 3551) or woodworking machinery (SIC 3553; Yost, 1984).

Assumptions

The following assumptions are made in pursuit of this study:

1. Manufacturing engineers employed in the manufacturing industry are a good source for obtaining skill and education competency information in their particular industry.

2. Respondents will report their true, accurate, sincere preferences on the questionnaire provided.

3. Manufacturing engineers are interested in assisting education and are willing to provide the needed data.

4. The functional industrial sector of manufacturing engineering as a discipline is representative of the knowledge and skills required for curricula development in manufacturing engineering technology programs.

Delimitations

This study will not address:

1. The general education classes required for graduates to be proficient in the manufacturing industry.

2. ABET manufacturing engineering curricula and competencies.

3. Non ABET accredited four-year manufacturing technology degree programs.

4. University and community college MET degree programs outside the state of North Carolina.

CHAPTER II

LITERATURE REVIEW

To assist in delineating the parameters of this study, a review of related literature and research was conducted. The review of literature contributed extensively to the generation of the MET competency list, the refinement of the variables which include, SIC classification (product type), the rural-urban location of each manufacturing plant, usage of manufacturing technologies, and the number of facility employees. Each variable was used in the final instrument to collect data.

The review of related literature is divided into the following sections:

1. Plant, Product, and Manufacturing Technology Diversity
2. Industry-University Linkages
3. Placement of MET Graduates
4. Related Studies

Plant, Product, and Manufacturing Technology Diversity

In a study sponsored by the Society of Manufacturing Engineers, Koska and Romano (1989) analyzed surveys and opinions of over 7500 manufacturing practitioners and reported on the anticipated changes in manufacturing and competencies required by MET graduates. They indicate changes in several areas including new products, product variation, global competition, global manufacturing technologies, and social and economic change. "These differences, accelerated by on-going changes in the markets, products, and technology, demand that manufacturing and manufacturing engineering be looked at in a new light" (Koska & Romano, 1998, p. 1). Global competition, increasing number of manufacturing technologies, and a focus on the demands of the customer are forecasted trends expected in the coming decade.

Shift from Large to Small Plants (number of employees)

Currently, five out of six American employees work in institutions with fewer than 1,000 employees (Carnevale, 1991). In North Carolina, 99.24% of all manufacturing SIC coded companies employ less than 1000 workers and 95.13% of all companies employ less than 375 (Harris Info, 1999).

Recent shifts in the number of employees through corporate downsizing and its effect on manufacturing productivity and skills is evident through research on small to medium sized industries. External competitive and social-economic influences have a significant effect on the manufacturing environment. As U.S. industries strive to face off global competitive forces, manufacturers have begun and will continue to shift from large complex plants to smaller plants (Sheridan, 1989).

Small business represents over 90% of the businesses in the United States (Fu, 1998). Pelham (2000) noted that firm size and industry characteristics have strong positive correlation with company performance. Results of the study indicate that market orientation for implementing growth and product differentiation is significant. Larger firms have lessened level of customer contact which leads to internally focused operations and production/technical orientations that may fail to adjust to customer demands, new products, and diversifying market conditions. Kotry and Meredith (1997) found smaller firms have higher emphasis on product improvement, product quality, new product development, and customer service. Small-business performance factors include emphasis on adopting new production methods and increasing employee productivity/production efficiency. Chasten and Mangles (1997) found that the most important influences on performance for small companies were customer quality expectations, developing new products and structuring the organization to optimize work-force effectiveness, including training for employees at all levels.

Schmenner and Lackey (1994) address the competency issue among small businesses and downsized companies.

Management and production jobs have been re-engineered out due to technical developments, commitment to improved materials management, and plant layout. These changes resulted in raising the technical competence of new production managers and engineers requiring advanced and multiple managerial and technical skills, particularly in JIT and information technologies. It was summarized that manufacturing engineers in smaller plants are more likely required to possess a broader range of competencies. K. Henry, (personal communication, April 30, 1999) a MET graduate and process engineer at a small Caterpillar plant in Franklin, NC, stated that in larger Caterpillar plants, manufacturing engineers require narrow specialized skills, where as smaller plants require broad based skills.

Modern Manufacturing Technologies and MET Competencies

The development of new manufacturing technologies in the past ten years has significantly affected the competencies required of manufacturing engineers and technicians entering the workforce. Mittelstade (1996) discussed the influence of personal computers on competencies required of new manufacturing engineers. Personal computer power is becoming a factor in nearly every stage of the production process from integrated CAD/CAM systems, integrated automation systems, and quality control.

Allred (1993) discussed the changing U.S. manufacturing paradigm and the manufacturing technologies accompanying this shift. Paradigm shifts to new automation in robotics, computerized real-time process control systems, and integrated MRP-II systems for enhanced material flow are being utilized to keep product development and cycle time short for improved customer service, reduce inventories, and shorter work-in-process times. The development and implementation of these systems require new competencies of manufacturing engineers and technicians.

> The problem for institutions, especially in technical areas, is how to keep pace with the rapid change in technology and produce a graduate qualified to compete on a global basis. One major concern for educational institutions is the high cost of equipment in the laboratories. A technical program must also identify those new and emerging technologies that need to be taught. (Zirbel, 1993, p. 1)

The New Economy and Divergent Product Types

Productivity, quality, variety, customization, convenience, and timeliness are organizational manufacturing strategies for the new economy. The implications associated with these strategies are having a profound effect on job designs, and manufacturing competencies. Carnevale (1991) addresses these changes by expanding on increased job complexity and job skills.

Employees will need to be flexible in order to live in a competitive framework of global competition. Traditional productivity was achieved by automating the rigid components of a work process, using more narrow purpose machinery requiring reduced skill requirements. In the new economy, flexible technologies will require more flexible skills of workers and engineers. Increased emphasis on soft competencies of communication and interpersonal skills are required to effectively interact with customers and transmit technical information relevant to producing high quality products. Additionally, information technologies and computer technologies in manufacturing are replacing repetitive intellectual tasks, reducing paper work and allowing networking capabilities for just-in-time deliveries, faster setups and reprogramming, thereby increasing timeliness, variety and customization (Carnevale, 1991).

The type of products produced in the new economy reflects a shift away from traditional machining and materials and their associated competencies, toward new composites, alloys and polymers, particularly in small businesses focused on product diversity. The rapid change of pace in today's global economy is causing products to become obsolete at an unprecedented rate. New technologies, substitute materials, changing consumer tastes, and shifting consumption patterns are shortening product life cycles and requiring companies to develop a steady stream of new products (Sandvig, 1998).

Weizer (1994) discusses the use of advanced materials such as specialty steels, aluminum, and engineered plastics in automotive applications. Customer demands of higher fuel economy, government safety regulations, and environmental recycling issues have driven automotive changes toward new materials. Multi-grades of steel such high strength steel, low alloy steel, and stainless steel will continue to dominate components of automobiles. Below are the percentage change in automobile steel contents between 1983 and 1998.

High Strength	4.1% increase
Low Alloy	7.1% increase
Stainless Steel	4.8% increase
Aluminum	9.6% increase
Engineering Plastics	9.6% increase

MET graduates will be exposed to new materials including environmental composites and coatings, high performance powder metallurgy, stainless steel for anti-lock braking systems, and polymeric materials for automotive exterior body panels designed to reduce weight, styling flexibility, greater damage resistance, and lower production costs. As a current example, advanced aluminum alloys have been developed by Dana Corp. to reduce cost, weight, power consumption, and noise levels (SAE, 1999).

Urban Affects on Manufacturing Technology

Knudsen (1994) investigated the influence of urban and rural adoption of flexible manufacturing cells (FMC). Several comparisons were drawn between independent (non-parent companies) and branch (multi-plant) plants. Branch plants tended to be urban facilities and adopted FMC later than independent plants. Quality and increased output were important reasons for the adoption of FMC in independent plants, whereas rural plants gave experimentation with new technology and labor-cost reduction as important reasons. Additionally, urban plants tended to be less flexible than rural plants in terms of production scheduling, and contained more levels of upper management. The increased use of upper management in urban locations coincides with experience by Henry (1999) who indicated smaller-rural plants require a broader set of MET competencies. Knudsen noted that urban plants had greater capital and information resources than their rural counterparts. Urban plants were less likely to have trouble achieving required machine utilization rates and had fewer bottlenecks using FMC after it was up and running. Management at urban plants was more familiar with benchmarking, statistical process control, and just-in-time concepts than their rural counter parts.

Manufacturing Technologies in the Rural South

Rosenfeld (1995) addressed two issues of the effect of manufacturing technologies on required skill levels. Corporate leaders and educators contend that advanced technologies require more cerebral skills, an ability to solve a variety of production problems, and a willingness to accept greater responsibility. Advocates of implementing advanced manufacturing computer technologies argue that higher-order skills, breath of knowledge, and knowledge of computer linked operations are significant.

Rosenfeld uses the term workers as production workers or machine operators. As manufacturing technologies become "turn-key" or automated will the skills of entry - level MET's also be diminished? With advances in CNC software technologies, the CNC programmer may not be required to understand the basic skills needed for CNC programming, be it at the worker or supervisory level. Researchers argue that technology is more likely to simplify and de-skill work than to upgrade it and can lead to intensified management control over workers. Flynn (1988) reinforces the argument that automation divides the work force, and as a result many jobs are de-skilled. Although higher skilled tasks are needed, computer-controlled machines have eliminated the need for tasks that previously required skilled craftsmen.

Rosenfeld's research supports the argument that technology adoption requires advances in skill levels. A survey of 147 employees in 14 southern small, rural automated firms showed a substantial increase in skill levels and participation in day-to-day decisions in a small number of firms, and showed a significant need for increased flexibility in the work force. Interviews of employees and engineering managers emphasized the need for highly skilled workers. "Smart responsible workers are needed to operate smart machines" and "Sophisticated equipment has to be run by reasonably sophisticated people" (Rosenfeld, 1991, p. 229).

What are the implications for MET competencies in rural southern states? North Carolina industrial extension service indicated that inadequately trained factory managers do not know how to deal with incoming technology and are barriers to modernization. A survey of the use of programmable automation found supervisors to be the least likely to be trained to understand and use the equipment, yet to supervise intelligently, they should be have hands-on experience. Bellwright Industries in South Carolina noted that degreed engineers lack the hands-on experience and fired several production engineers because "They were not willing to get out in the shop and get their hands dirty and their knowledge and interests were too theoretical" (Rosenfeld, 1995, p. 276).

North Carolina MET graduates often obtain supervisory positions in rural areas and with the adoption of new manufacturing technologies, southern MET graduates will be required to know as much and more than production workers and should be trained along with production workers. In terms of competencies in Southern rural manufacturing plants, hands-on experience in all technical areas is essential. Southern rural MET programs should emphasize the basics of manufacturing processes at the machine shop level, in addition to training on advanced manufacturing systems, software, and modern production management methods (Rosenfeld, 1995).

The Spectrum of Manufacturing Technology Utilization

The utilization spectrum of manufacturing technologies and thus the on the job competency requirements of MET graduates vary significantly. Knudsen (1994) surveyed machinery manufacturers in Illinois, Indiana, Michigan, Ohio, and Wisconsin on the utilization of flexible manufacturing cells, flexible labor cells, and concurrent changes in management operations. The population of companies surveyed were classified as non-electrical machinery, and small to medium sized firms organized as "job shops." Results indicate 66% responding had no flexible manufacturing capability (FMC).

Utilization of flexible manufacturing systems was affected by plant size. Smaller plants tend to have less access to capital and new production technology information than large plants, but large plants are less able to adapt quickly to new methods of production than small plants.

Beede (1998) sampled thousands of U.S. manufacturing plants and found enormous diversity in the levels, utilization, and adoption of manufacturing technology. Variables that contribute to this diversity are (a) varying degrees of association with new plant-level job creation, (b) productivity, and (c) earnings. The research investigated 10,000 plants in five manufacturing groups: fabricated metal products; industrial and commercial machinery and computer equipment; electronic and other electric equipment and components; transportation equipment; and instruments related products (SIC 34-38). The most important finding of the study is that technology adoption patterns of manufacturing plants exhibit enormous diversity, even within the same industry or the same production process. Table A1, shows the major technology grouping surveyed. Table A2 shows the detailed technologies investigated within these major groups. Notably, Beede (1998) found that 2 to 4% of 10,000 plants sampled use stand-alone technologies of computer-aided design and computer numerical control machine tools. Eighteen percent of these plants adopted unique manufacturing technology combinations that contributed to increased productivity. The technology combinations relative to productivity levels are listed in Table A3.

Industry-University Linkages

Due to competitive forces and new developments in manufacturing technology, industry has been the driving force behind changes in engineering and technology curricula. Strengthening the bond between industry and academia is vital to the future of engineering technology, and reforming curricula to achieve industry participation is essential (Lahndt, 1998). Mason (1998) surveyed 47 manufacturing companies in the Pacific Northwest to determine the current and future content of the manufacturing curriculum. Increased accountability from industry and the tax-paying public on the quality of college graduates has resulted in curriculum evaluations. Zargari (1999) surveyed working technology graduates to determine curriculum strengths, weakness, and relevancy. The editor of Manufacturing Engineering, responded "university curriculum developers must critically examine their offerings to ensure that they are delivering exactly what industry needs" (Coleman, 1991, p. 4). Owen (1994) emphasized that to be globally competitive manufacturing education must develop competencies required by industry. Global competition and customer driven products have forced industry to move toward system-integrated and flexible production processes.

Clark (1986) examined the function of regional university research in the areas of industrial productivity and technical assistance to manufacturing related to production and management methods. Regional research and service activities of educators should seek out and set as high priority service activities related to the outside community needs of business, industry, and government. Hill (1994) discussed methods used to determine the focus of the Technology Assistance Center at Weber State University. Surveys and interviews of industrial representatives from small to medium-sized industries were conducted to better serve the industrial educational needs of the region. The data revealed industry-education partnerships were required to provide industrial technical assistance and assist stimulating regional economic development. Kopp (1996) emphasized the need of university engineering and technology programs in electronics and manufacturing to expand their services to meet the educational needs of their surrounding service communities. These programs within the Purdue University Statewide Technology System recognized the need for industry involvement to increase enrollment and to keep curricula current with industrial technologies and manufacturing methods.

Clary (1983) in a study conducted by the Department of Occupational Education at North Carolina State University determined elements that affect an institution's ability to respond to the training needs of industry. Nineteen elements were identified as being important to a university's responsiveness to industry. Elements significant to this study include (a) high quality of instruction, (b) quick response to industry and follow-through by the institution, (c) tailoring of courses to meet the specific needs of industry, and (d) flexibility of the institution to meet the unusual needs of industry. The study strongly recommended that institutions respond to industry needs for training.

Williams (1994) addressed the need for Western Carolina University (WCU), located in the mountainous region of Western North Carolina, to engage in workforce development in order to (a) address the region's economic future impacted by global competitiveness, (b) assist industries affected by the regional shift from large corporations to small and medium sized manufacturing firms, and (c) provide technical support for regional industries attempting to implement advanced manufacturing technologies. The report proposed workforce development initiatives in the areas of (a) more rigorous academic programs for all young people; (b) strengthening collaboration between employers, community colleges, and WCU; and (c) developing adult education and training programs that anticipate the skill demands of emerging jobs.

Placement of MET Graduates

A thorough examination of the literature revealed no research on the placement of MET graduates according to SIC product classification. The notion of educators that MET graduates are placed mainly in the heavy-equipment, appliance, automotive or metal working industries has not been validated. The diversity of companies and the related competencies employing MET graduates can vary significantly. Major industry types vary from state to state. In North Carolina, 1422 firms are classified as textile SIC code 2200 ranking first in North Carolina manufacturing employment. Paper products accounted for employment of 24,805 people and ranked as the 13th largest employer in the manufacturing sector. Miscellaneous manufacturing sector SIC code 3900 employs 8,280 people at 331 establishments in North Carolina. SIC code 3300, Primary Metals Industry accounted for the employment of 17,306 peoples, with a rank of 15th among North Carolina's manufacturing industries.

The value of primary manufacturers' shipments in 1996 was $3.5 billion, a rank of 15th among North Carolina's manufacturing industries. There were 1,582 establishments under the SIC code 3500-Industrial & Commercial Machinery & Computer Equipment, employing 69,664 people statewide, ranking 8.5% of the entire state's workforce. Several areas in North Carolina contain heavily wooded terrain and national forests. SIC code 2400-Lumber and Wood Products, employed 42,806 statewide, ranked eighth in statewide employment, and contains 5% of the manufacturing workforce. Logging and furniture production is included in SIC code 2400. SIC code 3800-Instruments and Allied firms for Measuring and Controlling Devices, including equipment for the medical industry, employs 15,116 statewide and ranks 17th in manufacturing employment (NC Dept. Commerce, 1999). MET graduates finding professional employment within a wide spectrum of industries will be required a broad range of competencies beyond the traditional metal-working and heavy equipment industry.

It is clear that engineering technology graduates do take on engineering job titles. Mott (1992) researched engineering technology graduates over the last 25 years at the University of Dayton. Engineering Technology graduates were placed in the following employment functions: (a) General Management (6.3%), (b) Design-related Functions (31.1%), (c) Manufacturing-related Functions (28.0), (d) Sales/Service-related Functions (24.8%), (e) Other Technical Functions (8.0%), and (f) Other Non-Technical Functions (1.8%). Stratton (1999) performed a similar study and found that 62% of MET graduates held a professional title of engineer. Fowler (1980) surveyed employers of the bachelor engineering technology (BET) program at Georgia Southern College regarding several items including job titles, acceptance of BET graduates by employers, performance, educational preparation, and dependability. All areas were rated as either satisfactory or excellent.

Such research validated the technical competency of engineering technology graduates in the field but does not address the spectrum of industries employing engineering technology graduates. Edmonson (1999) found that between 1992 and 1996, 19.9% of all engineering and technology graduates form the University of Dayton were employed in manufacturing engineering/management positions and did publish a listing of some of the employers of engineering technology graduates. Edmonson noted that they were employed at "a wide variety of large and small firms" (Edmonson, 1999, p. 5), but the SIC spectrum nor the percentage of placement in small, medium, or large-sized plants, and the urban or rural location was not listed.

ABET has recognized the importance of MET graduates feedback by requiring accredited programs to conduct alumni survey, yet very limited research data are available on MET alumni perceptions of curriculum and the type of companies MET graduates find jobs (ABET, 2000).

Lack of research in the placement of MET graduates according to SIC product types supports this research variable as the entry-level MET competency questionnaire was sent and received from diverse SIC product types, indicating the employment of MET graduates.

Related Studies

Brown (1983) used the Delphi method to determine if competencies derived from the curriculum of the newly established MET program at WCU correlated with competencies as perceived by regional industry. The region investigated was a five-state territory surrounding WCU including bordering portions of Georgia, South Carolina, Tennessee, North Carolina, and Virginia. The purpose of this study was to determine if the competencies used in the MET program at WCU were acceptable for entry-level employment by industries in the defined service area.

A survey of ranked importance of entry-level tasks as perceived by industry experts in a five state region in surrounding Western North Carolina (WNC) were compared to the ranked order of importance as perceived by the Industrial and Engineering Technology (IET) faculty at WCU.

Results revealed that 51 of the 77 competencies were considered more important by IET faculty than by industry, with 14 competencies having significantly higher mean rating above the .05 level. Overall the study indicated that MET competencies at WCU did not correlate with the competencies defined by industrial managers in the region.

Brown (1983) recommended seeking additional assistance from industry in the form of program planning as a means of establishing more appropriate learning experience for students and indicated the need to replicate the study in a metropolitan industrial area in order to evaluate the location affect on industrial rated competencies.

Daniel (1992) developed a questionnaire to determine the competencies required of manufacturing supervisors in the electronics industry. Subjects consisted of 38 supervisors from attendees of an electronics manufacturing workshop. The study sought to determine if high-performing supervisors in the electronics industry would be seen by subordinates as displaying significantly greater levels of competencies. Nine competencies identified in the study significantly distinguished high-performing supervisors from other randomly selected supervisors. High-performing supervisors were found to demonstrate significantly higher levels of goal orientation, bottom-line orientation, initiative, collaboration and team building, systematic problem solving, image and reputation, and self-confidence. The study demonstrated that job and job-context specific requirements for exemplary performance is significant and that organization roles can be uncovered and operationalized. The study exemplifies this research of investigating manufacturing competencies significance according to diverse product types and facility demographics.

Yost (1984) surveyed the chief operating officers of 187 manufacturing facilities among five (SIC) groups in the state of Wisconsin to determine the competency tasks required of manufacturing engineers. The study sought to determine the level of importance of entry-level tasks required of manufacturing engineers as perceived by manufacturing firms in 1984 and five years in the future, and how those tasks vary according to plant size and SIC classification. The initial list of entry-level tasks was derived from (a) manufacturing engineers employed in Wisconsin, (b) opinions of experts within the School of Industry and Technology of the University of Wisconsin-Stout, (c) SME publications, (d) course descriptions from U.S. colleges and universities offering degrees in Manufacturing Engineering, Manufacturing Engineering Technology and Industrial Technology, and (e) a review of company publications. Entry-level tasks were categorized and ranked according to level of importance using descriptive statistics and analysis of variance to test for significant differences on each tasks according to plant size and SIC group.

The study examined the present and future ranked importance of entry-level tasks required of manufacturing engineers in the state of Wisconsin. The study determined that 93 out of 99 present time tasks in 10 different categories were considered as "somewhat important" to industry experts in the state of Wisconsin. Thirteen of the 99 tasks were considered "very important" at that present time. Fifty-six of the 99 tasks were considered "important" at the present time. Twenty-four entry-level manufacturing engineering tasks were rated "somewhat important." Six of the 99 tasks were considered "not important" in the present time. Tasks that were considered "very important" at the time of the study and five years in the future were (a) the ability to communicate effectively, (b) motivate others, (c) prototype new parts and products, (d) specify materials, (e) specify safe working conditions, (f) contribute to productivity improvements, and (g) justify equipment expenditures. Additional tasks considered "very important" five years in the future included (a) human interaction, (b) manufacturing planning, (c) manufacturing research and development, (d) manufacturing practice, and (e) manufacturing control.

From an analysis of competency rankings according to plant sizes and SIC classification, Yost generalized that manufacturing engineers employed by larger firms should be equipped with a broader set of competencies than their counterparts in smaller firms. The greatest variation in competency requirements according to product type occurred within the gray iron foundries and manufacturers of motors and generators SIC categories.

The Yost (1984) research addressed the competencies required of manufacturing engineers among selected industries in the state of Wisconsin. Tasks were partially derived from curricula content across various engineering and technology disciplines including manufacturing engineering programs, manufacturing engineering technology programs, and industrial technology programs. Each of these programs has a different purpose and function. Therefore, his findings on the affect of plant size on competencies for ABET/MET programs have not been validated for other states or the country as a whole. Due to the extremely rapid change in manufacturing technologies, the Yost study is outdated. Yost suggested a replication of his study in other fields of manufacturing (IT, MET, MT programs) to determine if results differ.

Tillman (1989) performed a Delphi study to determine fundamental competency areas to be used in the development of the SME Certified Manufacturing Technologies examination. The study identified 68 competency areas, 24 of these were emphasized in the examination. The three highest rated competencies were drafting and engineering drawing, human communications, and safety.

Zirbel (1993) performed a Delphi study and identified thirty-seven tasks as being needed by engineering technologists in the year 2000. The Delphi panel recommendations were incorporated into a second survey instrument that was used to validate the findings. Manufacturing firms in Texas validated these nation-wide findings. Zirbel recommended several areas of curriculum improvements including (a) development of strong work ethic and the concept of quality be emphasized in the curriculum. (b) oral and written communication be an integral part of all courses, (c) team projects be an integral part of course work, (d) methods of automation for improving quality and productivity be stressed in later courses, (e) teachers of MET programs should be prepared to continually upgrade their own competency with applications in manufacturing, and (f) that the competencies developed from his research be used as a basis of discussion to evaluate the content, level of importance, and the amount of time placed on MET activities when designing or revising MET curricula.

Discussing his results, Zirbel provided a stimulus for the present investigation calling for future research to include (a) a replicated study in other geographic regions with larger sample population, and (b) additional studies with various types of manufacturing industries and size of companies.

Nelson (1992) performed two Delphi studies and compared them. The first Delphi study of industrial experts determined more specific competencies from previous broad-based manufacturing engineering technology competencies determined by Miller (1989), Tillman (1989) and Zirbel (1993). Competencies identified by Miller (1989), Tillman (1989), and Zirbel (1993) were associated with SME certification, Industrial Technology programs or MET programs but were not specifically tied to ABET accreditation. In the second Delphi study, a survey was mailed to program directors of all ABET accredited MET programs to determine to what degree they perceive their graduates had attained the specific competencies identified by industrial members of the first Delphi panel.

Nelson found no significant difference between the rankings of the panel of industrial experts and the program directors. Using the Wilcoxon matched-pairs signed-ranked test on each of the SME major heading competencies also revealed no significant difference between rankings of the panel of industrial experts and ABET program directors.

Nelson (1994) concluded that (a) with the exception of four competencies, educators from ABET-accredited institutions are emphasizing the selected technical competencies in MET programs, (b) the competencies identified by the Delphi panelists can be used by MET educators to evaluate programs and to develop or revise courses, and (c) the rankings assigned to the competencies by both Delphi panelists and program directors support and validate the competencies identified by Zirbel (1993).

Although the Nelson (1992) study validated competencies on a national scale for ABET/MET programs, the study did not address the competency requirements according to the utilization of manufacturing technology, plant size, location, and product type. An investigation of ABET/MET competencies according to these variables is a current issue as addressed in subsequent headings. This study utilizes the most recent and validated research on MET competencies as addressed by Nelson (1992) as a validated standard from which to compare against the manufacturing technology and demographic variables.

The Society of Manufacturing Engineers (SME) developed a Manufacturing Education Plan (MEP) that identified competencies required of entry-level engineering and technology graduates. The MEP addressed competency requirements in manufacturing studies, manufacturing systems, quality, continuous improvement, physical control of machinery, manufacturing management, communications, product engineering, design-sciences, and mathematical tools. These competencies were derived from the automotive industry, machine tool industry, heavy equipment industry, aircraft and aerospace industry, and the electronics industry (SME, 1997). According to the MEP, manufacturing engineering competencies carried varying weight according to industry type. Competencies identified in the MEP were associated with each specific type of industry. "Thus, colleges and universities can identify the voice of their own industrial constituency and better focus on the perceived needs of the employers of their graduates" (SME, 1997 p. 34).

According to the above mentioned experts in the field, the mission and responsibility of manufacturing education reaches into the local and regional needs of industry. To meet regional and statewide needs, educators must know the skills and competency requirements of industry. This study will add to the body of knowledge by examining the degree of relationship between company production characteristics and the importance of ABET/MET competencies for a particular state. Previous research to establish ABET/MET competencies was done on a national scale, neglecting the affects of various company production characteristics and demographics.

Summary

Chapter two presented selected literature that examined the relationship between validated MET competencies as presented by Nelson (1992) and the independent variables of plant size, urban and rural plant location, utilization of manufacturing technologies, and the diversity of manufactured products. The first section dealt with the connection of small and large plants, modern manufacturing technologies, the new industrial economy, product diversification, plant location, and the utilization of manufacturing technologies to MET competencies. The second section examined the relationship between industry input and the development of MET competencies according to local and regional focus of educational institutions. The third section presented the diversity of employment opportunities in terms of job titles, industry type and size in which MET graduates are employed. The fourth section examined related studies in the development of MET competencies validated by Nelson and addressed the need for further research on competencies according to the independent variables.

The review of literature indicated that there has been a significant shift from large corporations to small manufacturing plants. Smaller firms are more customer-focused which leads to the introduction of diverse products. Downsizing has occurred due to several factors including manufacturing technological developments, which has raised the technical competence required of managers and engineers.

Urban located facilities incline towards adopting manufacturing technologies later in time than rural plants.

Thus, MET competencies in urban plants tend to require less technologically advanced skills. Urban plants tend to have higher number of upper level management thus requiring a narrower set of skills. Rural plants tend to have fewer upper level managers and engineers requiring more "catch all" type supervisors and engineers over specialized skills. Specifically, southern rural manufacturing companies tend to employ inadequately trained managers that do not know how to implement new and up-incoming technology, particularly in the area of programmable automation. Rural southern companies need more hands-on type engineers with experience in basic manufacturing skills in addition to advanced management, and automation skills.

The utilization of modern manufacturing technologies according to plant size vary and thus the competency requirements of MET's vary. Smaller manufacturers typically have less capital available for new equipment purchases, and have less access to new production methods and technologies. Large plants are not able to adopt new technologies quickly.

Industry-university relations are being strengthened in order to meet technical requirements of graduates. Industry is working with education to obtain graduates that can "hit the ground running." Viewing area industry as the customer, curriculum changes according to the local and region needs of industry have taken precedence over national standard MET competency. Research cites several examples (surveys) of where universities sought out curriculum content from industry. Regional universities are more involved in the economic and regional development and research activities should seek out and set as a high priority service activities addressing the needs of business and industry.

There are a wide variety of industries in which MET graduates could find employment. The literature shows that most find jobs that contain the title of engineer, but the scope of placement in terms of product type has not been researched. Thus the effect of this diversity on MET competencies has not been investigated. This is significant, as the traditional metal-working heavy industry base in U.S. is shrinking, plants are downsizing, and companies are producing new and diverse products.

The Nelson study validated MET competencies across the nation by surveying ABET MET faculty. His findings agreed with Zirbel, and Zirbel suggested further research on MET competencies in other geographic regions, with larger sample populations and studies that included various types of manufacturing industries and plant sizes.

In summary, literature supports the concept of investigating the strength of relationship between MET competencies and geographic entities of product type, plant location, plant size, and utilization of manufacturing technologies. The connection between these variables and MET competencies has not been established in literature, and is the focus of the present investigation.

CHAPTER III

METHODOLOGY

Collected data from practicing manufacturing engineers in manufacturing industries on the perceived importance of entry-level MET competencies were evaluated against usage of manufacturing technologies, product type, number of employees, and plant location. Data were analyzed using correlation analysis. Each manufacturing engineer was asked to provide information on his or her company's demographics and utilization of manufacturing technologies. The independent variables were the utilization (presence or absence) of manufacturing technologies, number of employees, plant location (urban or rural), and product type (SIC classification). The dependent variables were the respondent's rating (minimally important to extremely important) of the previously validated ABET/MET competencies. Regression research methodologies similar to this study were used by Gale (1998) to compare the extent of technology use as a function of rural-urban indicator variables, Laura (1998) to examine the relationship between productivity, investment and plant age over time, and by Chen (1996) to examine factors contributing to employee commitment in the implementation of flexible manufacturing systems.

Population

A computer database of 8,927 North Carolina manufacturing firms was obtained from North Carolina Advantage West Economic Development Agency. The database contained information on all SIC companies in North Carolina, including number of employees, mailing addresses, sales revenue, executive titles, and product description.

The United States SIC numbering system is published by the Statistical Policy Division of the United States Government. The SIC numbering system is used to classify all firms by activity to facilitate compilation and presentation of data. Division D, major groups 2000 to 3000 series numbers indicate manufacturing companies. The 4-digit number defines the specific industry within a subgroup. For example:

SIC	3XXX	is the designation for manufacturing.
	35XX	is the major group number for Industrial and Commercial Machinery and Computer Equipment.
	353X	is the sub group for Construction Machinery and Material Handling.
	3535	is the industry number for Conveyors and Conveying Equipment.

Major manufacturing SICs groupings investigated in this study are 2200, 2300, 2500, 2600, 3000, 3300, 3400, 3500, 3600, 3700, 3800, 3900. Below is a listing of the designation titles for each of these SIC major numbers.

Major Group 2200: Textile Mill Products.

Major Group 2300: Apparel and Other Finished Products Made From Fabrics and Similar Materials.

Major Group 2500: Furniture and Fixtures.

Major Group 2600: Paper and Allied Products.

Major Group 3000: Rubber and Miscellaneous Plastics Products.

Major Group 3300: Primary Metal Industries.

Major Group 3400: Fabricated Metal Products, Except Machinery and Transportation Equipment.

Major Group 3500: Industrial and Commercial Machinery and Computer Equipment.

Major Group 3600: Electronic and Other Electrical Equipment and Components, Except Computer Equipment.

Major Group 3700: Transportation Equipment.

Major Group 3800: Measuring, Analyzing, and Controlling Instruments.

Major Group 3900: Miscellaneous Manufacturing Industries.

Sample Selection

Four hundred and forty companies were randomly selected. This research initially examined 12 SIC independent variables (IVs), 2 urban/rural IVs, 3 plant size IVs, 3 level of technology IVs, and 1 dependent variable (competency category) for each regression equation.

Combining research questions reduced the number of required mailings. The selection of SIC major groups was done based on previous MET competency research by Yost (1984), Zirbel (1993), and Nelson (1992). SIC selections by these researchers included the traditional metal working groups of 3300, 3400, 3500, and 3600. Additionally, a review of North Carolina State Economic data was conducted to determine those SIC significant in terms of percentage of total manufacturing employment. North Carolina sustains a heavy textile, apparel, and furniture industry base with several MET graduates obtaining positions in these industry types (Office of State Planning, 1999).

<u>Survey Instrument</u>

This study used a questionnaire as the means of collecting data. The questionnaire was pilot tested for content and validity by two people from industry and four people from educational institutions. Minor revisions were made before it was mailed to 440 practicing engineers. Surveys were sent only to selected SIC groupings of companies in North Carolina. The survey was divided into three parts. Part 1 collected information on the professional profile of the respondent. Part 2 addressed utilization of manufacturing technologies, methods, and capabilities currently in use or under development.

Demographic data were collected in Part 2. Part 3 required the rating of MET competencies according to the perceived importance. Appendix B contains the complete cover letter and questionnaire.

Pilot Testing of the Instrument

The instrument was sent to six qualified individuals knowledgeable of MET competencies and modern manufacturing technologies and processes. The selection of these industry engineers came from the author's personal contacts with area manufacturing engineers. It was desired, but not required, that industrial jurors be SME certified manufacturing engineers or technologists. The industrial juror must have had at least five years manufacturing engineering work experience. Industrial Technology Department members of the dissertation committee were also asked to provide feedback on the instrument. Suggested changes from the committee members were implemented before sending the instrument to industrial representatives. The evaluators were asked to provide additions or deletions to the comprehensive listing of Manufacturing Methods and Manufacturing Technologies. Appendix B lists the expert jurors. Only minor changes in the instrument were required based on the recommendations of the jurors.

Collection of Data

The database of companies was exported into MicroSoft Excel format for subsequent analysis using SPSS Windows statistical software. Randomness of the SIC mailings was ensured through the use of the random number generator in Excel.

Mailing Procedures

1. Cover letter. Each survey pack contained a cover letter explaining the study to the respondent.

2. Number coding. All questionnaires were number coded according to the research question they addressed. A complete listing of all companies according to SIC product code and research question was saved for cross-reference for determining the number of non-respondents.

3. Self-addressed stamped return envelope. Each survey packet contained a stamped, self addressed return envelope.

4. No return date of the questionnaire was requested. Those engineers who did not respond were sent a follow-up postcard requesting completion of the instrument.

5. The data were to be coded and grouped into an Excel spreadsheet for descriptive statistical analysis and then imported in Windows SPSS for regression analysis.

Recording and Follow-up Procedures

The responses to each item on the survey were recorded into an Excel spreadsheet. As in Yost (1984), companies with less than 10 employees were not included in the mailings. Industries employing less than 10 people were not considered a typical environment where intermittent, batch, or continuous type production processes are present. This study took an identical approach to the minimum number of employees at a company to include that company in the population. To obtain a stratified random selection of companies according to number of employees and SIC number, random numbers were assigned separately to groupings of less than 50 employees, between 50 and 450 employees, and greater than 450 employees. After the responses were received, all of the respondents were divided into three divisions according number of employees to represent plant size of small, medium and large. Small companies with employees between zero and 160 were designated as small, between 161 and 350 were designated as medium and between 351 and 2200 as large plants. The mean value of each competency category was manually calculated and recorded as were the number of manufacturing technologies used. Six weeks following the initial mailing a follow-up reminder postcard was sent to all non-respondents.

Response Rate

"Completion rates on many mail questionnaires are notoriously low with figures of 40 to 50% considered good" (Warwick, 1975, p. 129). Of the 440 surveys sent out, 48 were returned. Three additional surveys were returned following the reminder postcard for a total of 50 respondents.

Analysis Procedure

Regression Analysis

The goal of multiple regression analysis is to investigate the strength of relationship between a dependent variable (DV) and several independent variables (IVs; Pedhazur, 1982). Regression analysis provides a means of objectively assessing the degree and character of the relationship between DV and IVs. Regression is used for prediction or correlation analysis. Correlation is used when the intent is to measure the degree of association between the DV and IVs. This study utilized the correlation element of regression analysis.

Regression requires the use of metric or continuous data, which means using interval or ratio data for both the independent and dependent variables. However, categorical (non-metric, nominal/ordinal) variables can be used. Categorical variables constitute a set of mutually exclusive categories that differ from each other in kind, but not in degree. Categorical variables are classified into groups such as occupation, marital status, or political affiliation. The independent variables in this study of manufacturing technologies are non-metric (yes/no in terms of a company's utilization of a manufacturing technology). Independent variables must be coded or assigned symbols to represent their group. Research Questions 1, 2, and 3 use seven categories (a) usage of technology, (b) plant size-small, (c) plant size-medium, (d) plant size-large, (e) plant location-urban, (f) plant location-rural, and (g) number of employees.

The dependent variables (four-year MET competencies) were also grouped, but not coded as they are metric data (interval/ratio data). Nelson (1992) validated 141 MET competencies which are separated into eight categories: Design for Production, Materials, Manufacturing Processes, Manufacturing Systems and Automation, Controls, Manufacturing Management/Quality and Productivity, Liberal Studies, and Capstone Courses. The manufacturing engineer's response rating of each individual competency under each category is averaged and an overall score obtained for each competency category. Regression was then run on each independent variable category against the dependent variable category mean (Hair, 1995).

Correlation Analysis

In addition to examining the strength of relationships through regression analysis, correlation hypothesis testing using the Pearson *r* correlation coefficient was utilized. Those variables with significant correlation are considered negative, or positive in the population. Additionally, point bi-serial correlation and significance was done on Research Question 3 requiring the investigation of dichotomous and continuous variables.

Descriptive Statistics

Research Questions 4 and 5 require descriptive statistics. The overall mean importance of each competency category according to SIC product grouping will be presented in Chapter 4, as will the overall perceived importance of each competency category.

CHAPTER IV

FINDINGS

This chapter contains an examination of the data obtained from 50 North Carolina firms in 3 size designations, 2 location designations, and 12 SIC classifications. Respondents were asked their opinions concerning the importance of competencies required of entry-level manufacturing engineers. The inquiry was made concerning the degree of importance of MET competencies. In all, 137 previously validated competencies were included and grouped into eight major categories. A total of 61 manufacturing technologies representing a broad spectrum in terms of currency and sophistication were presented to the respondent. Respondents checked those manufacturing technologies currently in use or under development at their facility.

A total of 440 questionnaires were mailed to manufacturing companies in North Carolina with 5 questionnaires returned as undeliverable. An additional 5 questionnaires were incomplete and were not used. A response rate of 11.6% was obtained for this research. Comparing this rate with the response rates in recent manufacturing literature (Mehra & Inman, 1992, 22.44% and Ward, Leong, & Boyer 1994, 30%), 11.6% appears to be useable, with certain power limitations, given 50 respondents. Stevens (1996) recommends a nominal number of 15 data points per predictor for multiple regression analysis.

Analysis of Hypotheses

The hypotheses were tested for their statistical significance using multiple regression and correlation analysis for Research Questions 1, 2, and 3. Descriptive statistics were used for analysis of Research Questions 4 and 5.

Hypothesis 1a performed correlation between the usage of technology for each competency category per each company that responded. Scatter diagrams and associated correlation values were determined by counting the number of technologies the respondent indicated on the survey versus the mean response of each competency category for each company. Table C4 shows the mean competency category ratings for each company. In order to determine whether usage of technology is an important variable when considering the importance of competencies, Hypothesis 1b was tested by performing regression analysis on the same data as in Hypothesis 1a. Hypothesis 1c involved computing the correlation between the count usage of technology per each company and the over-all mean response of each competency category for each company (the mean of the entire 137 competencies). Table C4 shows the mean response for each of all competencies per each company.

Hypothesis 2a involved computing the correlation between the number of employees and the mean of each MET competency category. Plant size was determined by dividing the entire data set into thirds. The first third were designated small, the second third as medium, and the last third as large. The actual groupings are 0-160 employees/small, 161-350 employees/medium, and 351-2200 employees/large. Plants were sorted according their number of employees, grouped according to small, medium, and large, then correlated against their corresponding mean response of each competency category. Table C5 shows the plant size groupings and their corresponding mean response per competency category. In Hypothesis 2b regression was run on the same dataset as Hypothesis 2a to determine if plant size is an important variable when considering the mean response of competency categories. In Hypothesis 2c, correlation was completed between plant size (all sized grouped together) and all MET competencies (all competency scores grouped together), per each company. In Hypothesis 2d, regression was computed on the same dataset as Hypothesis 2c to determine if plant size is an important variable using F

ratios. In Hypothesis 2e, correlation was run between all the plant sizes grouped together and the mean response of each competency category. In Hypothesis 2f, the same dataset used in Hypothesis 2e was run using regression to determine the importance of plant size as a whole when compared against each competency category mean.

In Hypothesis 3a point bi-serial correlation was completed between urban/rural location and the mean response of each competency category. Table C6 show plant location and mean competency category response for each company. In Hypothesis 3b regression analysis was completed on the same dataset as Hypothesis 3b to determine if plant location is an important variable when considering the mean response of each company category. Hypothesis 3c seeks to determine the correlation between plant location and the overall mean of all competencies. Table C7 shows the plant location and mean response of all competencies for each company.

Research Question 4 determines the overall competency category ranking based on the mean response ratings. Original rankings were "extremely important" (5), "very important" (4), "important" (3), "minimally important" (2), and "not important" (1).

Research Question 5 determines the overall ranked importance of competency categories based on rated responses per SIC classification.

Research Question One

Research Question 1 asks if there is a significant relationship between usage of manufacturing technology and each competency category. The independent variable (x axis) is usage of technology and the dependent variables (y axis) are each competency category. Each competency category was investigated using Pearson's correlation and linear regression analysis.

Hypothesis 1a

Hypothesis 1a states there is zero correlation between usage of technology and desired competency categories in the population. Table 8 points toward a positive correlation on competencies 4, 6, and 8 and negative correlation on competencies 1, 2, 3, 5,and 7. The effect is not significant on all competencies at $r(49) = .273$, $p < .05$, two tail.

Figures 1-8 presented in Appendix C show the scatter diagrams of each competency versus number of manufacturing technologies used. The negative sign of the *r* value indicates a reduced mean response of each competency category as the utilization of manufacturing technologies increase. A positive *r* value indicates an increase in the mean response of each competency category as the utilization of manufacturing technologies increase. It can be stated that correlation between usage of technology and individual MET competency categories does not appear to occur in the population.

Table 8
Correlation Each Competency Categories and Usage of Manufacturing Technologies

Competency Number	Competency	Pearson *r*
1	Design for Production	-.137
2	Materials	-.150
3	Manufacturing Processes	-.177
4	Manufacturing Systems and Automation	+.159
5	Controls	-.054
6	Mfg. Management/Quality & Productivity	+.020
7	Liberal Studies	-.005
8	Capstone Courses	+.167

Note. $r(49) = .2759$, $p < .05$, two tail

Hypothesis 1b

Hypothesis 1b states that the independent variable usage of technology is not an important variable in determining each competency category importance. The regression equation coefficients indicate corresponding correlation negative and positive slopes and are listed in Table 9.

Table 9
Regression Coefficients Competency Categories and Usage of Manufacturing Technologies

	Competency	bo	b1
1	Design for Production	4.015	-.0073
2	Materials	2.017	-.0073
3	Manufacturing Processes	3.721	-.0086
4	Manufacturing Systems and Automation	3.226	+.0074
5	Controls	3.370	-.0048
6	Mfg. Management/Quality & Productivity	3.621	+.0009
7	Liberal Studies	3.858	-.0002
8	Capstone Courses	3.792	+.0086

Figures 9-16 in Appendix C show the normal probability plots of the standard residuals for each competency category. The plot is strongly linear indicating that the distribution of standardized residuals is close to a normal curve. The t-regression statistic for the significance of the independent variable utilization of manufacturing technologies on all competencies is shown in Table 10.

Table 10
Regression *t* test Significance all Competency Categories and Usage of Manufacturing Technologies

Competency Number	Competency	*t*
1	Design for Production	-.9650
2	Materials	-1.064
3	Manufacturing Processes	-1.192
4	Manufacturing Systems and Automation	+1.128
5	Controls	-.3760
6	Mfg. Management/Quality & Productivity	+.0138
7	Liberal Studies	-.0310
8	Capstone Courses	+1.186

Note. $t(50) = 2.01$, $p < .05$, two tail

The effect is not significant on all competencies at *t* regression (50) = 2.01, $p < .05$, two tail. The squared *r* values in Table 11 indicate that a very small proportion of the total variability comes from the usage of manufacturing technologies and supports the small *t* and *r* values. It can be stated that usage of manufacturing technologies does not appear to be an important variable when considering the importance of individual MET competency categories.

Table 11
Squared *R* All Competency Categories and Usage of Manufacturing Technologies

Competency Number	Competency	R^2
1	Design for Production	.0186
2	Materials	.0225
3	Manufacturing Processes	.0282
4	Manufacturing Systems and Automation	.0253
5	Controls	.0028
6	Mfg. Management/Quality & Productivity	.0004
7	Liberal Studies	.00002
8	Capstone Courses	.0270

Hypothesis 1c

Hypothesis 1c states that there is zero correlation in the population between usage of technology and the overall importance of all MET competencies. Results show a small correlation value of .0001 which is not significant at $r(48) = .2787$, $p < .05$, two tail. Zero correlation exists between the overall mean response of all MET competencies and usage of manufacturing technologies.

Hypothesis 1d

Hypothesis 1d states that the usage of technology is not a significant variable in determining the overall importance of MET competencies. The R^2 is extremely low at .0000009%. The t-regression is .007 and is not significant at $t(50) = 2.01$, $p < .05$, two tail. Usage of technology does not appear to affect the overall importance of all MET competencies.

Research Question Two

Research Question 2 asks if there is a significant relationship between the number of employees and each MET competency category and for all competencies overall. Each competency category was investigated using Pearson's correlation and linear regression analysis. One respondent was not included due to incomplete data and required 49 degrees of freedom. Plant size was determined by dividing the entire data set into thirds. The first third were designated small, the second third as medium, and the last third as large. The actual groupings are 0-160 employees/small, 161-350 employees/medium, and 351-2200 employees/large. The distribution of plant sizes were sorted in ascending order, the first 16 were grouped as small plant size, the second 16 as medium plant size, and the final 16 were designated as large plant size.

<u>Hypothesis 2a</u>

Hypothesis 2a states there is zero correlation between plant size grouping small, medium, and large and each MET competency category in the population. Table 12 shows that the effect of plant size on each competency per plant size grouping is significant for Competency 3, Manufacturing Processes, large plant size, $r(15) = .482$, $p < .05$, two tail.

Note that a total of three correlations were significant using one tail testing. Large plant sizes indicated competencies three and four were significant at $r(15) = .412$, $p < .05$ one tail and medium plant size was significant for competency 3 at $r(15) = .412$, $p < .05$, one tail. Figures 17-19 in Appendix C show the scatter plots of those significant one and two tailed competencies. Plant size grouping large was equally split of positive and negative correlation. Plant size grouping medium contained seven positive correlation and one negative correlation. Plant size grouping small resulted in two positive and six negative correlation.

Table 12
Correlation Each Competency Category Grouped S, M, L, and Plant Size

Competency Number	Competency	Pearson r Small	Medium	Large
1	Design for Production	-.422	+.281	-.046
2	Materials	-.045	-.096	-.070
3	Manufacturing Processes	-.178	+.427	-.497
4	Manufacturing Systems and Automation	-.248	+.300	-.208
5	Controls	+.111	+.042	+.466
6	Mfg. Management/Quality & Productivity	-.057	+.009	+.336
7	Liberal Studies	-.218	+.130	+.301
8	Capstone Courses	+.152	+.001	+.296

Note.
Small $r(14) = .497$, $p < .05$, two tail
Medium $r(15) = .482$, $p < .05$, two tail
Large $r(15) = .482$, $p < .05$, two tail

Small $r(14) = .426$, $p < .05$, one tail
Medium $r(15) = .412$, $p < .05$, one tail
Large $r(15) = .412$, $p < .05$, one tail

Hypothesis 2b

Hypothesis 2b states that independent variables of small, medium and large plant sizes are not significant in determining each competency category. This analysis looked at the significance of each competency category compared against plant size of small, medium, and large. Table 13 shows the *F* values for analysis of small, medium and large companies. None of the *F* ratios were significant, therefore, no beta coefficients or *t*-values are reported. None of the *t*-regression coefficients were significant at $t(49) = 2.01$, $p < .05$, two tail.

Table 13
F - Ratio Each Competency Category Grouped S,M,L

Competency Number	Competency	*F*-Ratio
1	Design for Production	0.467
2	Materials	1.466
3	Manufacturing Processes	1.146
4	Manufacturing Systems and Automation	0.750
5	Controls	0.511
6	Mfg. Management/Quality & Productivity	1.065
7	Liberal Studies	1.536
8	Capstone Courses	1.137

Note. $F(2,37) = 3.19$, $p < .05$, two tail

Hypothesis 2c

Hypothesis 2c states that there is zero correlation between plant size (all sizes grouped together) and the overall importance of all MET competencies (all competency scores grouped together) in the population. Results indicate a correlation of .163 between the mean response of all MET competencies and all plant sizes grouped together. This value is not significant at $r(49) = .2759$, $p < .05$, two tail, nor at the one tail significance of $r(48) = .2353$, $p < .05$. Zero correlation exists between plant size and the importance of all MET competencies.

Hypothesis 2d

Hypothesis 2d states that the independent variable of plant size (all sizes grouped together) is not a significant variable in determining the overall importance of all MET competencies (all competency scores grouped together). The effect of plant size is not significant when considering the mean response of all MET competencies. Regression analysis shows a very small coefficient of .0001 and a regression t of 1.144 which is not significant at $t(49) = 2.01$, $p < .05$, two tail. The R^2 value is relatively low at 16.3%.

Hypothesis 2e

Hypothesis 2e states there is zero correlation in the population between plant size (all plant sizes grouped together) and each competency category. Table 14 points toward a positive correlation on competencies 1, 2, 5, 6, 7, and 8 and negative correlation on competencies 3 and 4.

The effect of plant size is significant for competency 5, controls having an *r* value greater than the critical value $r(48) = .2787$, $p < .05$, two tail. The negative correlation of the *r*-value indicates a reduced mean response of each competency category as the plant size increases. The positive correlation of the *r* value indicates an increase in the mean response of each competency category as plant size increases. Competencies 1, 2, 5, 6, 7, and 8 had positive correlation, one of these being significant. Note that competencies 3, 5, 7, and 8 were significant at $r(48) = .2353$, $p < .05$, one tail, indicating a directional correlation in the population. The review of literature supports a positive correlation, as the number of employees increase the broader and more important certain competencies become.

Table 14
Correlation Between Plant Size and Each Competency Category

Competency Number	Competency	Pearson r $r(48)$
1	Design for Production	+.057
2	Materials	+.020
3	Manufacturing Processes	-.275
4	Manufacturing Systems and Automation	-.025
5	Controls	+.289
6	Mfg. Management/Quality & Productivity	+.227
7	Liberal Studies	+.239
8	Capstone Courses	+.253

Note.
$r(48) = .2787$, $p < .05$, two tail
$r(48) = .2352$, $p < .05$, one tail

Hypothesis 2f

Hypothesis 2f states that independent variable plant size is not an important variable in determining each competency category importance. The regression equation coefficients indicate corresponding negative and positive slopes as listed in Table 15. The t-regression test for importance of an independent variable in the regression equation on all competencies for plant size is shown in Table 16. One regression equation shows that plant size is a significant variable in determining the importance of competency 5, Controls. The R^2 values in Table 13 indicates a reasonable regression model with the percentage of variance the mean response for each competency is explained by plant size reaching 8%.

Table 15
Regression Coefficients for Use of Each Competency Category and Plant Size

Competency Number	Competency	b0	b1
1	Design for Production	3.797	+.00006
2	Materials	2.875	+.00003
3	Manufacturing Processes	3.618	-.0003
4	Manufacturing Systems and Automation	3.4156	-.00002
5	Controls	3.048	+.0005
6	Mfg. Management/Quality & Productivity	3.556	+.0002
7	Liberal Studies	3.762	+.0002
8	Capstone Courses	3.905	+.0003

Note. bo = y intercept b1 = regression coefficient

Table 16

Regression *t* test Statistics All Competency Categories and Plant Size

Competency Number	Competency	t-statistic
1	Design for Production	+0.398
2	Materials	+0.139
3	Manufacturing Processes	-1.980
4	Manufacturing Systems and Automation	-0.170
5	Controls	+2.099
6	Mfg. Management/Quality & Productivity	+1.617
7	Liberal Studies	+1.712
8	Capstone Courses	+1.815

Note. $t(50) = 2.01$, $p < .05$, two tail

Table 17
Squared *R* All Competency Categories and Plant Size

Competency Number	Competency	R^2
1	Design for Production	.0033
2	Materials	.0004
3	Manufacturing Processes	.0758
4	Manufacturing Systems and Automation	.0006
5	Controls	.0840
6	Mfg. Management/Quality & Productivity	.0517
7	Liberal Studies	.0576
8	Capstone Courses	.0642

Research Question Three

Research Question 3 seeks to determine if the urban and rural location of a plant has any effect on the importance of each MET competency category and all competencies. Linear regression analysis and point-biserial correlation was used to determine the significance of this variable.

Hypothesis 3a

Hypothesis 3a states that there is zero correlation between plant location (urban/rural) and each MET competency category. Table 18 shows the point-biserial correlation of each competency compared against the urban and rural location of a manufacturing facility. None are significant at $r_{pb}(48) = .2787$, $p < .05$, two tail.

Table 18

Point-Biserial Correlation Each Competency Category and Number of Employees

Competency Number	Competency	Point-Biserial r_{pb} (48)
1	Design for Production	+.112
2	Materials	+.035
3	Manufacturing Processes	+.068
4	Manufacturing Systems and Automation	-.084
5	Controls	+.007
6	Mfg. Management/Quality & Productivity	+.044
7	Liberal Studies	+.191
8	Capstone Courses	+.202

Note. $r_{pb}(48) = .2787$, $p < .05$, two tail

Hypothesis 3b

Research Question 3b asks if there is a significant relationship between plant location and each MET competency category. Table 19 shows the F-ratio values for each competency when compared against plant location urban or rural. There were no significant F values at $F(1,48) = 4.04$, $p < .05$, two tail. Additionally, all t-regression values for each competency were not significant at $t(48)$ = 2.01, $p < .05$, two tail.

Table 19

F-Ratio Each Competency Categories Grouped Urban/Rural Plant Location

Competency Number	Competency	*F*-Ratio
1	Design for Production	0.621
2	Materials	0.060
3	Manufacturing Processes	0.228
4	Manufacturing Systems and Automation	0.352
5	Controls	0.002
6	Mfg. Management/Quality & Productivity	0.096
7	Liberal Studies	1.683
8	Capstone Courses	2.081

Note. $F(1,48)$, 4.04, $p < .05$, two tail

Hypothesis 3c

Hypothesis 3c states there is zero correlation between plant location (urban/rural) and the overall importance of all MET competencies. Results indicate a point serial correlation of .13 which is not significant at $r_{pb}(48)$ = .2787, $p < .05$, two tail.

Hypothesis 3d

Hypothesis 3d seeks to determine if plant location is a significant variable in determining the overall importance of MET competencies. In this case, all the MET competencies are averaged together and regressed against their respective plant location. Results indicate plant location is not a significant variable in determining the overall importance of MET competencies with at *F*-ratio of 0.679, $F(1,48) = 4.04$, $p < .05$, two tail. The t-regression of .8242 is not significant at $t(48) = 2.01$ $p < .05$, two tail.

Research Question Four

Research Question 4 investigated the overall perceived importance of each industrial desired competency.
In determining the level of importance, each respondent was given the opportunity to respond to each of the 137 competencies with a Number 1 to 5.

Importance of Individual Competencies

Extremely Important

Based upon mean scores, seven competencies of the total 137 (5.1%) are considered by manufacturing engineers to be extremely important and are identified in Table 16. Extremely important tasks involved five competency categories. Two competencies are in Group 8 Capstone Courses, two competencies are in Group 7-Liberal Studies, one competency in Group 6-Manufacturing Management/Quality and Productivity, one competency in Group 3-Manufacturing Processes, and one task is in competency Group 1-Design for Production.

Table 20
Individual Competencies Receiving Mean Scores of Extremely Important

Overall Rated Order	Competency	Mean Score
1	Understand the importance of quality - the importance of doing it right the first time.	4.68
2	Communicate oral and written messages in a clear, concise, and professional manner.	4.60
3	Demonstrate a work ethic that displays motivation, natural curiosity, and a sense of responsiveness without close supervision.	4.58
4	Read and interpret assembly drawings.	4.56
5	Understand and practice safe working conditions.	4.54
6	Listen and understand problems and difficulties that occur in manufacturing (participate in team deliberations).	4.54
7	Learn to get the job done right, without any excuses, and on schedule with minimal supervision	4.52

Very Important

Based upon mean scores, 92 of the 137 (67.15%) competencies are considered by respondents to be very important and are identified in Table 17. Very important tasks appeared in all 8 competency categories. Nineteen (20.6%) tasks are in competency Group 1: Design for Production. Eight (8.7%) are in competency Group 3: Manufacturing Processes. Ten (10.8%) are in competency Group 4: Manufacturing Systems and Automation. Two (2.1%) are in competency Group 5: Controls. Thirteen (14.1%) are in competency Group 6: Manufacturing Management/Quality and Productivity. Twenty-nine (31.5%) are in competency Group 7: Liberal Studies, and 11 (11.9%) are in competency Group 8: Capstone Courses.

Table 21

Individual Competencies Receiving Mean Scores of Very Important

Overall Rated Order	Competency	Mean Score
1	Demonstrate personal ethics and be able to apply them.	4.50
2	Understand process strength/weakness.	4.40
3	Define costs-effective manufacturing processes (knowing strengths and weaknesses of each manufacturing process).	4.38
4	Understand the basic working knowledge of personal computers.	4.38
5	Provide clear, concise work instructions and procedures to shop personnel.	4.36
6	Develop time management skills.	4.34

(Table Continues)

Overall Rated Order	Competency	Mean Score
7	Find out manufacturing production personnel real needs and problems.	4.32
8	Share workload and credits with the team.	4.32
9	Maintain loyalty to the company and department - ensuring goals are met regardless of outside influences. (care about your company as if you owned it).	4.30
10	Recognize conditions/circumstances that constitute "trouble spots" in manufacturing a product.	4.28
11	Understand part application and development to ensure functionality (how things are put together).	4.24
12	Work in a "team" environment that requires compromising for the "good of the whole."	4.24
13	Understand the importance of a clean workspace.	4.22
14	Write memos/reports quickly, clearly, and with proper grammar.	4.22
15	Balance personal and professional life.	4.22
16	Provide leadership and an example in quality operation.	4.20
17	Communicate effectively with other team members and ensure that your own work and team members work is completed on time.	4.20
18	Understand the manufacturing environment.	4.16
20	Understand tolerance stacking.	4.14
21	Understand drafting techniques (i.e. orthographic, isometric, and pictorial views).	4.12
22	Identify bottlenecks.	4.12
23	Manage and implement projects within schedules and budgetary constraints.	4.12
24	Prepare technical reports.	4.12
25	Analyze the nature of parts rejection to determine the cause and devise preventative measures.	4.10
26	Know how to learn new processes quickly.	4.10
27	Have working knowledge of different types of software for various applications - - word processing, database spreadsheet, design, presentation, etc.	4.06

(Table Continues)

Overall Rated Order	Competency	Mean Score
28	Develop and/or utilize systematic problem solving techniques.	4.04
29	Understand what motivates employees.	4.04
30	Communicate with other departments (marketing, manufacturing, etc.) to transmit manufacturing perspective.	4.02
31	Understand basic production, flow of work, facilities layout.	4.02
32	Be able to "sell" an idea.	4.02
33	Understand the methodology of effective brainstorming.	4.02
34	Provide the development team with knowledge of specific process capabilities (including cost and times for processes).	4.00
35	Know how to "learn to learn" (life-long learning).	4.00
36	Understand sexism, racism, and politics.	4.00
37	Understand geometric dimensioning and tolerancing.	3.98
38	Conduct business in a manner consistent with local customs.	3.98
39	Understand simple logical methods.	3.98
40	Understand the "no-free-lunch" principle - recognize the necessity of compromise - appreciate the "cost" of actions and in-actions.	3.98
41	Assume authority and responsibility until someone stops you.	3.98
42	Assist in the preparation of technical specifications (write procedural instructions).	3.94
43	Perform mathematical calculations. Note this competency was reorganized under "Liberal Studies."	3.94
44	Understand what is expected in safety and health.	3.94
45	Integrate skills taught in various courses in an integrated project.	3.92
46	Evaluate existing conditions with regard to established standards or policy and recommend specific changes to correct unsafe conditions.	3.92
47	Analyze and evaluate quality performance in existing manufacturing operations.	3.92

(Table Continues)

Overall Rated Order	Competency	Mean Score
46	Evaluate existing conditions with regard to established standards or policy and recommend specific changes to correct unsafe conditions.	3.92
47	Analyze and evaluate quality performance in existing manufacturing operations.	3.92
48	Recognize that the best solution meets the needs of all departments/operations (politically sensitive, but don't compromise to reach a poor implementation).	3.92
49	Demonstrate the ability to create time management plans, money, facilities budgets, and achievements for oneself.	3.90
50	Understand the concept of simplest manufacturing process applicable to the job.	3.88
51	Determine equipment process capabilities.	3.86
52	Understand SPC, quality, variability, how to make measurements.	3.86
53	Request/recommend modifications to processes, procedures and designs.	3.86
54	Identify and eliminate non-value added operations.	3.84
55	Conduct objective data collection and analysis, and arrive with valid conclusions.	3.84
56	Demonstrate the ability to recognize problems in personal work environment/discuss practicality of solving them.	3.84
57	Resolve an unstructured problem.	3.84
58	Learn to sort through key information on a report, and act on it as required.	3.82
59	Practice simplicity of thought to operations.	3.80
60	Provide accurate estimates of the time required in performing manufacturing operations.	3.78
61	Understand the handling and disposal of hazardous materials.	3.78
62	Understand issues associated with the environment in the workplace (health and safety concerns).	3.78
63	Understand basic machining operations and equipment.	3.76
64	Understand the safety data sheets (MSDS).	3.76

(Table Continues)

Overall Rated Order	Competency	Mean Score
65	Understand the process of simplification before automation.	3.74
66	Know who (in-house and outside) can develop and troubleshoot PLC applications.	3.74
67	Identify manufacturing resources (and alternatives) needed for product production.	3.72
68	Determine the need for automation/human assistance to offset bottlenecks.	3.72
69	Prepare and give technical presentations with good graphic aids.	3.70
70	Identify requirements for sequential operations.	3.68
71	Understand design-for-assembly.	3.68
72	Understand assembly methodologies and techniques.	3.68
73	Train production personnel in the proper application of current technology and the implementation of new technology.	3.68
74	Understand environmental interactions of manufacturing processes.	3.68
75	Expose yourself to your profession (conferences, seminars).	3.68
76	Understand common manufacturing standards called for on drawings (ANSI, MIL, DOD specs.), including bill of materials and process plan.	3.66
77	Understand OSHA guidelines.	3.66
78	Participate in/contribute to teams developing assembly cells and systems.	3.64
79	Devise product-testing methodologies with industrial engineers.	3.64
80	Understand handling of hazardous chemicals.	3.64
81	Represent manufacturing on a multi-disciplinary product development team to ensure producibility of new products.	3.62
82	Apply knowledge of a wide variety of manufacturing processes.	3.62
83	Observe successive manufacturing operations and devise methods of combining them into a single operation.	3.62
84	Develop a global (company) perspective.	3.58
85	Understand work place worker rights and responsibilities.	3.58

(Table Continues)

Overall Rated Order	Competency	Mean Score
86	Understand process planning.	3.56
87	Understand principles and applications of just-in-time.	3.54
88	Verify that installed control equipment operates correctly.	3.54
89	Understand industrial standards (ANSI, DOD, ISA, ISO 9000).	3.54
90	Work with design engineers to inject producibility and testability features at the concept stage.	3.52
91	Identify conditions that require non-standard operations.	3.52
92	Assist suppliers in correcting their manufacturing problems.	3.51

<u>Important</u>

As indicated in Table 18, 37 tasks of the 137 (27.0%) are considered to be important. All competency categories contain important tasks. But the predominate number of important competencies are those listed under Group 5: Controls. Nine Controls competencies constitute 24.3% of important competencies. Seven competencies (18.9% of important competencies) were considered important in Manufacturing Management/Quality and Productivity. Seven (18.9%) competencies were of the competency group Manufacturing Processes. Six (16.2%) competencies were considered important in Group 4: Manufacturing Systems and Automation. Group 7: Liberal Studies contained five competencies (13.5%), Group 2: Materials contained two competencies listed as important. One competency (2.7%) was considered important in Capstone Courses.

Table 22
Individual Competencies Receiving Mean Scores of Important

Overall Rated Order	Competency	Mean Score
1	Demonstrate working knowledge of an operating system (DOS, UNIX, Windows, etc.).	3.50
2	Understand chemical applications and safety concerns.	3.50
3	Understand and specify different control techniques - pneumatic, and electrical.	3.46
4	Define process applications, generate supplier specifications and implement equipment into manufacturing, within schedule constraints.	3.46
5	Understand Just-In-Time and Kanban principles.	3.46
6	Know what "flexible" and "integrated" manufacturing are, and their application.	3.44
7	Understand human psychology.	3.44
8	Understand the benefits of networking computing devices.	3.40
9	Select the proper tooling and parameters for machining operations (metals), (know how to make a part).	3.38
10	Design/specify tooling and fixtures.	3.36
11	Understand post-manufacturing problems (solid waste).	3.36
12	Understand access and use of manufacturing databases.	3.34
13	Understand the business, market, and customers.	3.32
14	Understand engineering economy formulas/concepts and understand and calculate time/value of money.	3.32
15	Understand technical language and cultural problems associated with world-wide manufacturing.	3.32
16	Understand basic materials knowledge of metals including machinability for manufacturing.	3.28
17	Knowledgeable of material handling and automated systems.	3.28

(Table Continues)

Overall Rated Order	Competency	Mean Score
18	Learn PLC's applications/uses in manufacturing and how to change/modify PLC to meet requirements.	3.26
19	Understand closed - loop control.	3.24
20	Understand the basics of materials replenishment and inventory control.	3.24
21	Understand the principles of Deming.	3.24
22	Interface controls, sensors and interlocks to a PLC.	3.22
23	Recommend and develop appropriate technology for automation in manufacturing cells.	[illegible]
24	Understand ladder logic and other techniques.	3.20
25	Design tools, dies, jigs, etc. for the production process.	3.18
26	Estimate tooling requirements for a production run.	3.18
27	Verify that a PLC program performs correctly.	3.18
28	Understand basic materials handling applications.	3.16
29	Integrate off the shelf control equipment into new and existing manufacturing operations.	3.16
30	Use date gathering equipment such as CMM and digital measuring equipment.	3.16
31	Integrate PLC with process equipment.	3.10
32	Estimate raw material requirements for a production run.	3.06
33	Understand the value of computer modeling.	2.98
34	Understand basics of CAD-to-CAM-to-machine tool interfaces.	2.96
35	Develop computer aided engineering of flexible manufacturing systems (FMS) and integrated flexible-automated factory floor systems as a member of a multi-disciplinary team.	[illegible]
36	Program a CNC machine (specify correct cutter/feed speeds, machine set-up, correct cutter for application, and know how to make a part).	2.80
37	Analyze a CNC program that is producing out-of-spec parts and make necessary corrections.	2.78

Minimally Important

Only one competency was considered minimally important to entry-level MET graduates, grouped in competency category 2-Materials: Understand the injection molding process and related plastics applications.

Not Important

Zero competencies were considered not-important. Although several competencies did receive scores as not important, competency ratings were based on the mean response of all respondents.

Importance of Competency Categories

Based upon mean scores, competency categories are rated on the order of importance as listed in Table 19.

Table 23
Competencies Categories Mean Scores (All Data)

Overall Rated Order	Competency Category	Mean Score
1	Capstone Courses	4.00
2	Design for Production	3.85
3	Liberal Studies	3.82
4	Manufacturing Mgt./Quality Productivity	3.60
5	Manufacturing Processes	3.49

(Table Continues)

Overall Rated Order	Competency Category	Mean Score
6	Manufacturing Systems and Automation	3.39
7	Controls	3.24
8	Materials	2.92

Research Question Five

Research Question 5 examined the overall perceived importance of each industrial desired competency according to SIC groupings? Zero questionnaires were received from SIC group 2300, Apparel and Other Finished Products Made From Fabrics and from SIC group 3900, Miscellaneous Manufacturing Industries. The following Tables 20-29 contain the rated importance of MET competencies for SIC major groups 2200-3800.

Table 24

Competency Category Mean Scores 2200 SIC Classification

Textile Mill Products

1	Capstone Courses	4.00
2	Liberal Studies	3.94
3	Manufacturing Mgt./Quality & Productivity	3.88
4	Design for Production	3.75
5	Controls	3.50
6	Manufacturing Systems and Automation	3.09
7	Manufacturing Processes	2.78
8	Materials	2.50

Table 25

Competency Category Mean Scores 2500 SIC Classification

Furniture and Fixtures

Rated Order	Competency Category	Mean Score
1	Design for Production	4.27
2	Manufacturing Processes	4.06
3	Capstone Courses	3.95
4	Liberal Studies	3.80
5	Manufacturing Mgt./Quality & Productivity	3.68
6	Manufacturing Systems and Automation	3.38
7	Controls	2.64
8	Materials	2.33

Table 26
Competency Category Mean Scores 2600 SIC Classification
Paper and Allied Products

Rated Order	Competency Category	Mean Score
1	Capstone Courses	4.70
2	Controls	3.91
3	Liberal Studies	3.89
4	Materials	3.33
5	Manufacturing Mgt./Quality & Productivity	3.19
6	Manufacturing Systems and Automation	3.20
7	Manufacturing Processes	2.88
8	Design for Production	2.80

Table 27
Competency Category Mean Scores 3000 SIC Classification
Rubber and Miscellaneous Plastics

Rated Order	Competency Category	Mean Score
1	Capstone Courses	4.03
2	Controls	3.93
3	Liberal Studies	3.87
4	Manufacturing Mgt./Quality & Productivity	3.86
5	Design for Production	3.81
6	Manufacturing Processes	3.58
7	Manufacturing Systems and Automation	3.43
8	Materials	3.33

Table 28
Competency Category Mean Scores 3300 SIC Classification
Primary Metal Industries

Rated Order	Competency Category	Mean Score
1	Design for Production	3.80
2	Manufacturing Systems and Automation	3.44
3	Capstone Courses	3.43
4	Manufacturing Processes	3.31
5	Manufacturing Mgt./Quality & Productivity	3.19
6	Liberal Studies	3.14
7	Materials	2.67
8	Controls	2.27

Table 29
Competencies Categories Mean Scores 3400 SIC Classification
Fabricated Metal Products

Rated Order	Competency Category	Mean Score
1	Controls	4.02
2	Capstone Courses	3.94
3	Liberal Studies	3.93
4	Design for Production	3.80
5	Manufacturing Mgt./Quality & Productivity	3.63
6	Manufacturing Processes	3.44
7	Manufacturing Systems and Automation	3.28
8	Materials	2.67

Table 30
Competency Category Mean Scores 3500 SIC Classification Industrial and Commercial Machinery and Computer Equipment

Rated Order	Competency Category	Mean Score
1	Capstone Courses	3.90
2	Design for Production	3.79
3	Liberal Studies	3.78
4	Manufacturing Mgt./Quality & Productivity	3.62
5	Manufacturing Processes	3.58
6	Manufacturing Systems and Automation	3.44
7	Controls	3.05
8	Materials	2.85

Table 31
Competency Category Mean Scores 3600 SIC Classification Electronic and Other Electrical Equipment and Components, Except Computer Equipment

Rated Order	Competency Category	Mean Score
1	Design for Production	4.45
2	Capstone Courses	4.29
3	Liberal Studies	4.08
4	Manufacturing Systems and Automation	3.71
5	Manufacturing Mgt./Quality & Productivity	3.66
6	Manufacturing Processes	3.47
7	Materials	3.17
8	Controls	3.08

Table 32
Competency Category Mean Scores 3700 SIC Classification
Transportation Equipment

Rated Order	Competency Category	Mean Score
1	Capstone Courses	4.09
2	Design for Production	4.00
3	Liberal Studies	3.94
4	Manufacturing Mgt./Quality & Productivity	3.86
5	Manufacturing Processes	3.55
6	Manufacturing Systems and Automation	3.42
7	Controls	3.38
8	Materials	2.96

Table 33
Competency Category Mean Scores 3800 SIC Classification
Measuring, Analyzing, and Controlling Instruments

Rated Order	Competency Category	Mean Score
1	Capstone Courses	3.83
2	Liberal Studies	3.60
3	Design for Production	3.38
4	Manufacturing Mgt./Quality & Productivity	3.27
5	Manufacturing Processes	3.23
6	Manufacturing Systems and Automation	3.13
7	Materials	2.67
8	Controls	2.55

Summary of Statistical Results

Chapter four was arranged in five sections to corresponding to the five null hypotheses of the study. The analysis focused on the differences between plant demographics and usage of manufacturing technologies and the mean response of MET competency categories. All data were analyzed by Pearson's correlation, point biserial correlation, and linear regression. Descriptive statistics were presented on the importance rating of MET competencies overall and per SIC groupings. The analysis indicated significant differences ($p < .05$, two tail) on 3 of the 14 null hypotheses.

The statistical findings provide support for the objectives of the study. In short, the analysis indicated that demographic variable and degree usage of manufacturing technologies do affect MET competency ratings.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The central problem of this study was to assess the rated importance of previously validated ABET/MET competencies in the state of North Carolina and determine how plant location, plant size and usage of manufacturing technologies affect importance.

The overall purpose of this study was to determine the influence of demographic variables for curriculum development given reliability of utilizing a standard set of ABET-MET competencies given the role of regional universities to meet the industrial expectations of their constituency, particularly when the constituent voice represents diverse or specific manufacturing technologies, and demographic characteristics.

The review of literature supports the potential correlation between the independent variables of plant size, plant location, usage of manufacturing technologies, and number of employee and MET competency ratings. The null hypothesis is stated as the reverse of what is actually believed or shown in the review of literature. The literature review leaned toward the influence of the independent variables on MET competencies therefore the null approach is taken. The null hypothesis states that the independent variable does not affect MET competencies versus rejection would have meant that the independent variable affects competencies. Failure to reject the null hypothesis can be the result of several confounding factors including inadequate sample size, motivational factors affecting respondents' responses peculiarities, length of the survey, and survey sample distribution among companies in North Carolina.

The goal of this research is to detect the influence of the independent variables in MET competencies.

The specific objectives of the study were to answer the questions:

1. Is there correlation between usage of manufacturing technology and the importance of MET competencies?

2. Is the effect of usage of manufacturing significant in determining the importance of MET competencies?

3. Is there correlation between plant size and MET competencies?

4. Is the effect of plant size significant in determining the importance of MET competencies?

5. Is there correlation between the location of a plant and the importance of MET competencies?

6. Is the effect of plant location significant in determining the importance of MET competencies?

7. What is the importance rating of MET competencies in North Carolina?

8. What is the importance rating of MET competencies according to SIC classification in North Carolina?

Summary

Review of Literature

Due to lack of directly related studies on the effect of certain demographics on MET competencies, the review of literature considered elements that held logical ties; the diversity of new manufactured products, recent shifts from large to small plants, recent development of modern manufacturing technologies and their effect on MET competencies, the new economy and its implications on job designs and manufacturing competencies, the urban effects of plant location on the utilization and adoption of manufacturing technologies, manufacturing skills in the rural south, the spectrum of manufacturing technology utilization throughout in America, industry-university relationships in addressing curricula content, and the diversity of companies employing MET graduates.

Related research studies to determine what manufacturing competencies are required by industry for a broad range of engineering/technology programs including industrial technology, manufacturing engineering, manufacturing technology and manufacturing engineering technology and their importance were addressed by Yost (1984) and Tillman (1989). Competencies specific to the ABET/MET curricula and their rated importance were addressed by Brown (1983), Zirbel (1993), and Nelson (1992).

<u>Designating the Population</u>

The 6,927 North Carolina manufacturing firms in main SIC category, manufacturing and with sub-grouping SIC headings 2200, 2300, 2500, 2600, 3000, 3300, 3400, 3500, 3600, 3700, 3800 and 3900 were considered for this study. A computer program was used to determine which SICs had adequate number of firms, and which firms varied sufficiently in size to permit small, medium and large breaks. Each SIC grouping often contained over 1000 companies. Random numbers were generated and associated with each company. Subsequently, the top 35 companies in each SIC were selected for survey distribution.

<u>Identification of MET Competencies</u>

Research by Nelson (1992) developed MET competencies from the previous work of Zirbel (1993), Tillman (1989), Miller (1989), and the Society of Manufacturing Engineers (SME) Curricula 2000 (Arthur, Wells, & Demers, 1986). The Nelson competencies were validated for ABET MET programs throughout the U.S.

Zirbel and Nelson did not investigate the effect of various demographic variables or the degree of utilization of manufacturing technologies, both of which vary widely per region, state and industry type. Zirbel recommended additional research related to his study to include (a) a replicated study in other geographic regions, with larger sample population and (b) additional studies with various types of manufacturing industries and size of companies.

Taking these competencies as baseline reference, this research sought to determine if various demographic variables affected the importance of competencies.

Survey Instrument to the Panel of Experts

Before the survey was mailed, a panel of experts knowledgeable in the field of manufacturing engineering technology was established for reviewing the instrument. These representatives included manufacturing engineers from area industry and educators in the four-year manufacturing technology field. Appendix B contains the list of qualified jurors. Jurors were selected according to their knowledge of MET programs and a minimum five years of manufacturing engineering working experience.

Analysis of Data

Four types of statistical tools were used in the analysis of data. They include linear regression, Pearson's correlation, point biserial correlation, and descriptive statistics. Categorical regression was used for dichotomous variables of plant size and location. Significant tests were conducted for correlation, t-regression, F-regression (ANOVA) and point biserial. Analysis of regression models investigated beta coefficients and r-square values. Significance testing was obtained to a 95% confidence level, two tailed, on all cases with noted one tail observations on Research Question 2e.

Findings

Bias and Error in Sampling

The generation of companies for survey distribution was done using a database provided by Advantage West Economic Development Commission of Western North Carolina. Companies were assigned a random number and those companies were included in the survey mailing, thus ensuring each company within the scope of the research had an equal chance of being selected. The surveys were distributed randomly according to SIC, and plant size. However due to the small return rate, it can be stated with high probability that a random responses were not obtained. Small return rates suggest response bias by SIC classification, plant size, plant location.

Non-sampling errors in terms of personal characteristics are possible. Uncontrollable factors such as the respondent's attitude and enthusiasm toward the subject can contribute toward undesirable variability. Induced bias of personal prejudices are possible and may vary with the employment title of the person completing the survey.

The survey was directed toward shop floor manufacturing engineers. However surveys were actually completed by a range of manufacturing and human resource personnel. Bias could have occurred due to the educational background of these individuals. Personnel responding with an engineering undergraduate degree could have scored competencies containing applied theory elements higher than competencies containing hands-on type skills. Supervisors holding MBA degrees could have rated operation research skills higher than hands-on skills.

Bias due to constrained dependent variables of the survey is also possible. The lowest value was set at 1 and highest set at 5. The respondent may have wanted to rate some competencies below a one or higher than a five.

External Validity

This study failed to draw a large sample from the population of interest and thus the ability to generalize from it is significantly compromised. The elements of geographical bias between rural and urban companies left out companies that could have contributed to the study.

Usage of Technology and MET Competencies

The review of literature points toward a broad number of variables that affect the adoption and utilization of manufacturing technologies and their associated manufacturing competencies. The expectation that as the utilization of manufacturing technologies increase, so does the importance of MET competencies, was not found to be significant for each competency category. As indicated by low t-regression coefficients, the variable usage of manufacturing technology is not an important variable when considering each competency category.

In terms of all competencies, as opposed to each competency category, and their correlation with usage of manufacturing technologies, non-significant positive correlation was found. The variable usage of technology as important was not significant when considering all MET competencies.

Plant Size and MET Competencies

Are MET competencies less important at larger plants? Findings indicate that for competency category 3-Manufacturing Processes, there exists a significant correlation within large facilities. Medium-sized plants considered competency 3, Manufacturing Processes significant at one tailed level. Additionally, large sized plants considered competency 5-Controls significant at one tailed level. However, the importance of plant size as a significant variable in regression analysis showed non-effective F-ratios.

A comparison between all MET competencies categories and all plant size data grouped together revealed a positive but non-significant correlation. Correlation shows that as plant size increased so does the importance of all MET competencies. Again, the importance of plant size as a significant variable in regression analysis showed non-effective F-ratios.

A comparison between all plant sizes grouped together (no categories) and each competency category showed competency category group 5-Controls significant. Competency categories 3, 5, 7, and 8 were significant at the one tailed level. Table 30 summarizes the significant results of plant size and competency importance.

Table 34
Summary of Research Question Two Significant Findings

Statistic	Comparison	Competency	No.
Correlation	Size (Large)/Comp. Category	2T	3
Correlation	Size (Grouped all)/ Comp. Category	2T	5
t-regression	Size (Grouped all)/ Comp. Category	2T	5
Correlation	Size (Large)/ Comp. Category	1T	3
Correlation	Size (Medium)/ Comp. Category	1T	3
Correlation	Size (Medium)/ Comp. Category	1T	5

Plant Location and MET Competencies

Does plant location influence the importance of MET competencies? This data indicates that location is not a significant variable and there is not significant correlation between location and MET competency importance.

Importance of MET Competencies in North Carolina

The overall importance of MET competencies resulted in 5.1% as "extremely important" with most of competencies coming from categories 7-Liberal Studies and 8-Capstone Courses. Sixty-seven percent were rated "very important," with the highest percentage (20.6) coming from competency Group 1: Design for Production. Twenty-seven percent of all MET competencies were rated "important" with the highest percentage (24.3) of important competencies coming from group five-Controls. One competency was considered "minimally important" and zero competencies were considered "not important." Note that several competencies did receive scores as "not important," competency ratings were based on the mean response of all respondents.

Importance of MET Competencies Per SIC Grouping

The importance of MET competencies varies per industry type. Table 23 lists the importance of MET competencies for all SIC listings investigated. The diversity of importance rating across various SIC groupings supports the industry-university curricula development methods presented in the review of literature.

Conclusions

The following conclusions address the overall purpose of this study and are based on an analysis of this data. No attempt is made to generalize the conclusions to other populations.

1. The results of this study cannot necessarily be generalized to the population, state, region, or other MET programs. This survey was mailed to 440 randomly selected practicing manufacturing engineers in North Carolina. The sample size was 50. The study had a response rate of 11.4%.

2. Within the sample, there is very little correlation between usage of manufacturing technology and the importance of each MET competency category.

3. The variable usage of manufacturing technologies is not an important factor when considering the importance of MET competencies.

4. There is very little correlation between plant size and each MET competency category.

5. Plant size is an important variable when considering a each competency category and all competencies.

6. There is very little correlation between plant location (urban/rural) and the importance of each MET competency category.

7. Plant location (urban/rural) is not an important variable when considering the importance of overall MET competencies.

8. Liberal Studies and Capstone Courses were highest rated "extremely important" competency categories. Competency Group 1: Design for Production, was the highest rated "very important" category. Competency Group 5: Controls, was the highest rated "important" competencies. There were very few "minimally important" and "not important" rated competencies.

9. The importance of MET competencies across selected SIC grouping varies. Table 19 lists the importance of MET competency categories across all SICs.

Discussion of Problems

1. One problem was that the list of competencies was too long for respondents to maintain their continuity of thought throughout the questionnaire. Possibly an initial face-to-face meeting or at least telephone contact might have proven useful in achieving increased involvement and interest on the part of respondents. This additional information concerning the purpose and design of the study might have countered some of the deleterious effects from long lists in rating the survey.

2. Another difficulty experienced in this study was that despite the request for manager to pass the study along to shop floor manufacturing engineers, many of the plant managers, to whom the instrument was addressed, passed it along to other managers or personnel for completion.

3. Surveys traditionally have had low response rates, a different strategy of contacting respondents should be used, possibly phone calls or interviews.

4. Appropriate sample sizes are required to obtain confidence on inferring the results to the population. "When an investigator anticipates a certain effect size

(ES), sets a significance criterion (.05), and then specifies the amount of power he desires, the n which is necessary to meet these specifications can be determined" (Cohen, 1988, p. 14). Cohen defines effect size as the degree to which the null hypothesis is false and that the effect size for null hypothesis in the population is zero. Given a realistic small population effect size of .10 in the population, and a desired power level of 80% requires a sample size of 783. Small, medium, and large effect sizes are defined as .10, .30 and .5 respectively (Cohen, 1988). Cohen (1969) guidelines show an effect size of .2 as small resulting in a required sample size of 193 for a power level of 80%. Power is the probability of correctly rejecting a false null hypothesis (Gravetter & Wallnau, 1996). Power for this study with an effect size of .20 gives a 29% power level.

In regard to the non rejection of several hypothesis in this study, Cohen states

> An analysis which finds that power is low should lead one to regard the negative results (non rejection) as ambiguous since failure to reject the null hypothesis cannot have much substantive meaning when, even though the phenomenon exists (to some given degree), the *a priori* probability of rejecting the null hypothesis was low. (Cohen, 1988, p. 4)

Implications for Educators

Traditionally as a result of funding limitations, technology programs have lagged industry in terms of equipment and technical training. As agents of technology transfer to state and regional industries, universities should strive to be leaders in the application advanced manufacturing technologies and management methods. Competencies developed by the work of Nelson (1992) and SME should serve as baseline foundations of instruction, however, it is recommended that administrators of MET programs consider demographic affects and the importance of specific competencies required by their state and regional based industrial constituency. No standard set of validated MET competencies can be applied across diverse regional and statewide demographics. As universities are accountable to the tax-paying pubic and supplying industry with qualified graduates, educators should listen to the voice of their customers in determining modern and relevant competency-based instruction. This research supports the effects of diverse demographic effects on the importance of MET competencies.

Recommendations for Further Research

The following recommendations are made under the premise that no single study can provide the information required for a comprehensive curriculum reform. Institutions are unique in their geographic location, clientele, governing board, and other controlling factors, thus, curriculum enhancements should address the constituents of a program.

1. Survey MET graduates to determine the exact representation of SIC companies of which they are employed. No data are available on the spectrum of SIC companies that employ MET graduates. Such information would provide more accurate data on the importance of MET competencies.

2. Replicate this study on a regional level. Employing firms would be closer in proximity to each other and a better sampling would be obtained. Further, the firms would better relate to the regional university and seek to assist a university in their region compared to a university outside their region.

3. Additional research on industry-university linkages for MET programs is needed. Are universities really listening to the voice of their customers and addressing their needs in terms of qualified students and curricula content? How many MET programs are actively involved in regional competency based instruction and what methods are being utilized to incorporate industry input?

4. Research on state and regional adoption of new manufacturing technologies is needed to assist in developing MET curricula and competencies. There is only scarce literature on the adoption of and dispersion of new manufacturing technologies in the state of North Carolina. Such information would provide educators with guidelines on curricula content.

5. Research is needed on the current status of desired MET competencies in rural manufacturing companies.

6. MET competency based research is needed that addresses the need of small production facilities in a region or state. What curricula content is needed to address the needs of small production facilities?

7. A valid national survey should determine what are the desired of entry-level MET graduates per SIC listings and their usage of technology. It should establish a matrix of usage of technology, location, size, SIC, and MET competency importance such that an educator can review his situation with respect to local industry SIC representation, urban-rural location, number of employees, and determine what specific competencies employers are looking for and subsequently incorporated into the curriculum.

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APPENDIX A

RELATED TABLES ON MANUFACTURING TECHNOLOGIES

Table A1
Technologies Surveyed By Major Technology Group

Group Number	Group Titles
1	Computer Aided Design or Related Technologies
2	Flexible Manufacturing
3	Robotics
4	Automated Material Handling
5	Automated Sensors
6	Communications Networks
7	Programmable Manufacturing Control

Table A2

Technologies Surveyed Within Each Major Technology Group

Group Number	Manufacturing Technology
1	Computer aided design and / or computer aided engineering
1	Digital representation of computer aided in procurement activities
2	Numerically or computer numerically controlled machines
2	Materials working lasers
2	Flexible manufacturing cells or systems
3	Pick and place robots
3	Other robots
4	Automatic storage and retrieval systems
4	Automatic guided vehicle systems
5	Automatic sensor based inspection and/or test equipment performed on incoming or in process materials
5	Automatic sensor based inspection and/or test performed on final product
6	Local area networks for technical data
6	local area networks for factory use
6	Inter-company computer network linking plant to subcontractors, suppliers, and/or customers
7	Programmable logic controllers
7	Computers used for control on the factory floor

Table A3
Technologies Combinations Relative To Productivity Levels

Technology Combination	% Growth
Local Area Network for Factory Use	26.6
Computer Aided Design and Local Area Network for Exchange of Technical Data	23.0
Computer Aided Design, Numerical Controlled Tools, Programmable Logic Controllers and Factory Floor Computers	14.7
Programmable Logic Controllers, Numerically	12.0
Controlled Tools, and Programmable Logic	10.6
Seven or more combined technologies	9.4

APPENDIX B

COVER LETTER, QUESTIONAAIRE AND QUALIFIED JURORS

Richard Temple
MET Coordinator
Department of Industrial & Engineering Technology

Dear Sir/Ma'am:

I am seeking your assistance in a competency study of 4-year undergraduate Manufacturing Engineering Technology (MET) degree programs offered at North Carolina Universities. Your firm was selected as a potential employer of MET graduates. This questionnaire was directed to you because as a practicing manufacturing engineer, you are in excellent position to provide the information needed. Your assistance in this effort is greatly appreciated. If you are not a manufacturing engineer or closely related to production activities, please forward this survey to a manufacturing engineer.

This study is intended to determine which technical competencies should be included in classroom and laboratory instruction for MET programs in North Carolina, and determine the demographic effect on the importance of these competencies. Based on your product SIC classification, it was determined that graduates from a MET program might be employed in a first post-graduate position at your company.

Although your name, job title, and other identifying data have been requested, be assured that all data will be treated only in a statistical sense, and that all responses will remain anonymous. This information will be used later in contacting you for forwarding a copy of the final findings, should you wish to receive them.

The purpose of this study is two-fold. One is better serve North Carolina industries by providing instruction that best represents the industrial constituency for this degree program. The other is to fulfill partial requirements needed to complete my doctoral program.

Your help is needed on what I consider to be a very important project. Global competitive forces are influencing the manufacturing base of this country and highly competent graduates are needed as future leaders. Additionally, one of the major purposes of a regional university is to provide relevant education to current and future employers like yours. The Department of Industrial & Engineering Technology at Western Carolina University is continuously seeking ways to improve the effectiveness and quality of their programs and services, and we need you help to determine how to best meet the needs of industry. You and your company are the most reliable source of meaningful feedback. Although the questionnaire is lengthy, it is an accurate method of how to best determine the competencies you require of our graduates. Again, your cooperation and consideration in this study is greatly appreciated.

Sincerely,

Richard Temple

An Analysis of Manufacturing Facility Characteristics and Four - Year MET Competencies for ABET Accredited Programs in North Carolina.

There are three sections to this survey, your professional profile, technological characteristics of your company, and MET competency ratings.

Section I Instructions

In order to ensure validity and creditability to this study, please provide some information about your professional position.

Section II Instructions

In Section II indicate those production characteristics and technologies that are currently in use or under development at your facility. Place a check mark by the manufacturing technologies, methods, capabilities, etc. currently in use or under development at your facility.

Section III Instructions

In Section III please rate each competency as you perceive important for an entry-level position requiring a B.S. degree in Manufacturing Engineering Technology at your company. Use the below scale. Possibly there is a competency you would require of a MET graduate that is not listed. On the last page list any additional competencies or knowledge areas you would require of an entry - level MET graduate and their importance.

Not Important	= 1
Minimally Important	= 2
Important	= 3
Very Important	= 4
Extremely Important	= 5

SECTION I YOUR PROFESSIONAL PROFILE

Name: ____
Job
Title: ____
Company Name: ______________________________________
Brief Job
Description: _______________________________________
____
____

Highest Degree Obtained: ____AS ____ BS ____MS
____Doctorate

Area of Specialization in each degree:
AS ____

BS ____

MS ____

Doctorate ____

Number of Years in Manufacturing Engineering. Please Circle
(1 - 5) (6 - 10) (11 - 15) (15 or more)

SECTION II COMPANY PROFILE

Please place a check mark by the following manufacturing technologies or methods currently in <u>use</u> or <u>under development</u> at your facility.

<u>Quality</u>

_____ Coordinate Measuring Machines (CMM)
_____ ISO 9000
_____ Automated Quality Data Acquisition Hardware and Software (stand alone systems)
_____ Automated Quality Data Acquisition Hardware and Software (networked systems)
_____ Vision System for Quality Applications
_____ Total Quality Management (TQM) Applications
_____ Use of higher level statistical tools for industrial problem solving. (ie, regression analysis, design of experiments, Taguchi method)

_____ Deming's Quality Principles
_____ Use of Quality Deployment Functions
_____ SPC Control Charts and Techniques
_____ Six Sigma Quality Measurement

Product Design Capabilities
_____ Manual Drafting
_____ 2-D Drafting - ie Autosketch
_____ 3-D CAD System
_____ 3-D Parametric Design CAD Software
_____ Rapid Prototyping Machine
_____ Finite Element Analysis Software
_____ Modal Analysis Hardware and Software
_____ Geometric Dimensioning and Tolerancing
_____ Design for Manufacturing

Management

_____ Just - In - Time Inventory Management
_____ Materials Requirement Planning (MRP) paper implementation
_____ Materials Requirement Planning (MRP) computer implementation
_____ Forecasting Techniques
_____ Capacity Planning Methods
_____ Value - Added/Non - Valued Added Analysis
_____ Time & Motion Analysis
_____ Ergonomic Standards
_____ KANBAN Systems
_____ PUSH Production Systems
_____ PULL Production Systems
_____ Economic Order Quantity (EOQ) or similar Demand System Management method.
_____ Group Technology

Machining

_____ APT (Automatic Programming Tool) for CNC code generation.
_____ 2 - D CNC Code Simulation and Generation from Graphic Input Software

_____ 3-D CAM/CNC Code Simulation and Generation from Graphic Input Software. Examples: (MasterCAM, CAMAX, SurfCAM,)

_____ CAD/CAM data network communication to shop floor.
_____ Tape driven CNC machine tools.
_____ Manual machine tools.
_____ You use three or less axis machine tools.
_____ You use more than three axis machine tools.
_____ You use predominately ENGLISH units of measurements.
_____ You use predominately METRIC units of measurements.

Automation, Computers & Networking

_____ Manufacturing Simulation Software
_____ Ethernet, TCP/IP, or similar LAN for plant data distribution.
_____ Intranet web based data distribution.
_____ Process Operations requiring programming in C++, Visual C++, Visual Basic or similar programs.
_____ Process Operations using Device Net, Profibus or similar Field Bus Protocals.
_____ Process Control GUI using Siemens - WINCC, National Instruments - LabView or WonderWare or similar packages.
_____ Process Control using Programmable Logic Controllers (PLCs) - Stand-alone
_____ Process Control using Programmable Logic Controllers (PLCs) - Networked
_____ Automated Material Handling Equipment
_____ Robots for Production Processes, Assembly, Material Handling
_____ Flexible Manufacturing Cells
_____ Flexible Assembly Systems
_____ Computer -Aided Plant Layout/Design
_____ Lasers Technology for Manufacturing Processes
_____ Use of Knowledge Based Systems or Expert Systems in Manufacturing Processes.
_____ Wide Area Network (WAN)
_____ Computer Aided Process Planning (CAPP)
_____ Bar Code Reading

Corporate Demographics

_____ Urban Location
_____ Rural Location
_____ Number of Employees at your plant?

SECTION III COMPETENCY RATINGS

COMPETENCY 1 - DESIGN FOR PRODUCTION

Entry-level graduates with a B.S. Manufacturing Engineering Technology should be able to:

DESIGN/DRAFTING

1.0 Read and interpret assembly drawings. 1 2 3 4 5

1.0.1 Understand geometric dimensioning and tolerancing. 1 2 3 4 5

1.0.2 Understand drafting techniques (ie. orthographic, isometric, and pictorial views). 1 2 3 4 5

1.0.3 Understand part application and development to ensure functionality (How things are put together). 1 2 3 4 5

1.0.4 Understand common manufacturing standards called for on drawings (ANSI, MIL, DOD specs.), including bill of materials and process plan. 1 2 3 4 5

1.0.5 Understand tolerance stacking. 1 2 3 4 5

MANUFACTURING TEAMWORK AND PRODUCT DEVELOPMENT

1.1 Represent manufacturing on a multi-disciplinary product development team to ensure producibility of new products. 1 2 3 4 5

1.1.1 Work with design engineers to inject producibility and testability features at the concept stage. 1 2 3 4 5

1.1.2 Communicate with other departments (marketing, manufacturing, etc.) to transmit manufacturing perspective. 1 2 3 4 5

1.1.3 Provide the development team with knowledge of specific process capabilities (including cost and times for processes). 1 2 3 4 5

1.1.4 Identify manufacturing resources (and alternatives) Needed for product production. 1 2 3 4 5

SCHEDULING

1.2 Identify requirements for sequential operations. 1 2 3 4 5

1.2.1 Provide accurate estimates of the time required in performing manufacturing operations. 1 2 3 4 5

LABOR STANDARDS AND MEASUREMENTS

1.3 Identify bottlenecks. 1 2 3 4 5

1.3.1 Determine the need for automation/human assistance To offset bottlenecks. 1 2 3 4 5

1.3.2 Identify conditions that require non-standard operations. 1 2 3 4 5

THE MANUFACTURING ENVIRONMENT

1.4 Understand the manufacturing environment. 1 2 3 4 5

1.4.1 Understand basic production, flow of work, facilities layout. 1 2 3 4 5

1.4.2 Define costs-effective manufacturing processes (knowing strengths and weaknesses of each manufacturing process). 1 2 3 4 5

1.4.3 Understand process strength/weakness. 1 2 3 4 5

COMPETENCY 2 - MATERIALS

Entry-level graduates with a B.S. Manufacturing Engineering Technology should be able to:

2.1 Select the proper tooling and parameters for machining operations (metals),(know how to make a part). 1 2 3 4 5

2.1.1 Understand the injection molding process and related plastics applications. (know how to make a part). 1 2 3 4 5

2.1.2 Understand basic materials knowledge of metals including machinability for manufacturing. 1 2 3 4 5

COMPETENCY 3 - MANUFACTURING PROCESSESS

Entry-level graduates with a B.S. Manufacturing Engineering Technology should be able to:

MACHINING OPERATIONS

3.1 Understand basic machining operations and equipment. 1 2 3 4 5

3.1.1 Program a CNC machine (specify correct cutter/feed speeds, machine set-up, correct cutter for application, and know how to make a part). 1 2 3 4 5

3.1.2 Analyze a CNC program that is producing out-of-spec parts and make necessary corrections. 1 2 3 4 5

3.1.3 Estimate raw material requirements for a production run. 1 2 3 4 5

3.1.4 Understand basic materials handling applications. 1 2 3 4 5

3.1.5 Design, specify tooling and fixtures. 1 2 3 4 5

3.1.6 Understand the concept of simplest manufacturing process applicable to the job. 1 2 3 4 5

3.1.7 Design tools, dies, jigs, etc. for the production process. 1 2 3 4 5

3.1.8 Estimate tooling requirements for a production run. 1 2 3 4 5

WORKING SAFETY

3.2 Understand and practice safe working conditions. 1 2 3 4 5

3.2.1 Knowledge of safety equipment requirements/applications (safety guards, etc.) 1 2 3 4 5

3.2.2 Understand the importance of a clean workspace. 1 2 3 4 5

3.2.3 Understand OSHA guidelines. 1 2 3 4 5

3.2.4 Understand the handling and disposal of hazardous materials. 1 2 3 4 5

3.2.5 Understand the safety data sheets (MSDS). 1 2 3 4 5

3.2.6 Evaluate existing conditions with regard to established standards or policy and recommend specific changes to correct unsafe conditions. 1 2 3 4 5

COMPETENCY 4 - MANUFACTURING SYSTEMS AND AUTOMATION

Entry-level graduates with a B.S. Manufacturing Engineering Technology should be able to:

4.1 Identify and eliminate non-value added operations. 1 2 3 4 5

4.2 Apply knowledge of a wide variety of manufacturing processes. 1 2 3 4 5

4.3 Practice simplicity of thought to operations. 1 2 3 4 5

4.4 Know what "flexible" and "integrated" manufacturing are, and their application. 1 2 3 4 5\

4.5	Understand basics of CAD-to-CAM-to-machine tool interfaces.	1 2 3 4 5
4.6	Understand process planning.	1 2 3 4 5
4.7	Understand the process of simplification before automation.	1 2 3 4 5
4.8	Participate in/contribute to teams developing assembly cells and systems.	1 2 3 4 5
4.9	Understand principles and applications of just-in-time.	1 2 3 4 5
4.10	Understand design-for-assembly.	1 2 3 4 5
4.11	Observe successive manufacturing operations and devise methods of combining them into a single operation.	1 2 3 4 5
4.12	Knowledgeable of material handling and automated systems.	1 2 3 4 5
4.13	Understand assembly methodologies and techniques.	1 2 3 4 5
4.14	Understand the value of computer modeling	1 2 3 4 5
4.15	Develop computer aided engineering of flexible manufacturing systems (FMS) and integrated flexible-automated factory floor systems as a member of a multi-disciplinary team.	1 2 3 4 5
4.16	Understand access and use of manufacturing databases.	1 2 3 4 5

COMPETENCY 5 - CONTROLS

Entry-level graduates with a B.S. Manufacturing Engineering Technology should be able to:

5.1	Integrate off the shelf control equipment into new and existing manufacturing operations.	1 2 3 4 5
5.2	Verify that installed control equipment operates correctly.	1 2 3 4 5
5.3	Verify that a PLC program performs correctly.	1 2 3 4 5
5.4	Know who (in-house and outside) can develop and troubleshoot PLC applications.	1 2 3 4 5
5.5	Integrate PLC with process equipment.	1 2 3 4 5
5.6	Learn PLC's applications/uses in manufacturing and how to change/modify PLC to meet requirements.	1 2 3 4 5
5.7	Understand closed - loop control.	1 2 3 4 5
5.8	Understand and specify different control techniques - pneumatic, and electrical.	1 2 3 4 5

5.9 Understand ladder logic and other techniques. 1 2 3 4 5

5.10 Interface controls, sensors and interlocks to a PLC. 1 2 3 4 5

5.11 Define process applications, generate supplier specifications and implement equipment into manufacturing, within schedule constraints. 1 2 3 4 5

COMPETENCY 6 - MANUFACTURING MANAGEMENT/ QUALITY AND PRODUCTIVITY

Entry-level graduates with a B.S. Manufacturing Engineering Technology should be able to:

6.1 Understand the importance of quality - the importance of doing it right the first time. 1 2 3 4 5

6.2 Analyze the nature of parts rejection to determine the cause and devise preventative measures. 1 2 3 4 5

6.3 Provide leadership and an example in quality operation. 1 2 3 4 5

6.4 Analyze and evaluate quality performance in existing manufacturing operations. 1 2 3 4 5

6.5 Recognize conditions/circumstances that constitute "trouble spots" in manufacturing a product. 1 2 3 4 5

6.6 Assist suppliers in correcting their manufacturing problems. 1 2 3 4 5

6.7 Determine equipment process capabilities. 1 2 3 4 5

6.8 Understand SPC, quality, variability, how to make measurements. 1 2 3 4 5

6.9 Provide clear, concise work instructions and procedures to shop personnel. 1 2 3 4 5

6.10 Understand industrial standards (ANSI, DOD, ISA, ISO 9000). 1 2 3 4 5

6.11 Request/recommend modifications to processes, procedures and designs. 1 2 3 4 5

6.12 Manage and implement projects within schedules and budgetary constraints. 1 2 3 4 5

6.13 Understand the business, market, and customers. 1 2 3 4 5

6.14 Understand the basics of materials replenishment and inventory control. 1 2 3 4 5

6.15 Understand Just-In-Time and Kanban principles. 1 2 3 4 5

6.16	Understand engineering economy formulas/concepts and understand and calculate time/value of money.	1 2 3 4 5
6.17	Use date gathering equipment such as CMM and digital measuring equipment.	1 2 3 4 5
6.18	Understand the principles of Deming.	1 2 3 4 5
6.19	Recommend and develop appropriate technology for automation in manufacturing cells.	1 2 3 4 5
6.20	Devise product-testing methodologies with industrial engineers.	1 2 3 4 5
6.21	Train production personnel in the proper application of current technology and the implementation of new technology.	1 2 3 4 5

COMPETENCY 7 - LIBERAL STUDIES

Entry-level graduates with a B.S. Manufacturing Engineering Technology should be able to:

7.1	Communicate oral and written messages in a clear, concise, and professional manner.	1 2 3 4 5
7.2	Prepare technical reports.	1 2 3 4 5
7.3	Write memos/reports quickly, clearly, and with proper grammar.	1 2 3 4 5
7.4	Listen and understand problems and difficulties that occur in manufacturing (participate in team deliberations).	1 2 3 4 5
7.5	Be able to "sell" an idea.	1 2 3 4 5
7.6	Find out manufacturing production personnel real needs and problems.	1 2 3 4 5
7.7	Assist in the preparation of technical specifications (write procedural instructions).	1 2 3 4 5
7.8	Prepare and give technical presentations with good graphic aids.	1 2 3 4 5
7.9	Learn to sort through key information on a report, and act on it as required.	1 2 3 4 5
7.10	Understand the basic working knowledge of personal computers.	1 2 3 4 5
7.11	Perform mathematical calculations. Note this competency was reorganized under "Liberal Studies."	1 2 3 4 5
7.12	Have working knowledge of different types of software	

for various applications - word processing, database spreadsheet, design, presentation, etc. 1 2 3 4 5

7.13 Demonstrate working knowledge of an operating system (DOS, UNIX, Windows, etc.). 1 2 3 4 5

7.14 Conduct business in a manner consistent with local customs. 1 2 3 4 5

7.15 Understand technical language and cultural problems associated with world-wide manufacturing. 1 2 3 4 5

7.16 Conduct objective data collection and analysis, and arrive with valid conclusions. 1 2 3 4 5

7.17 Understand simple logical methods. 1 2 3 4 5

7.18 Understand the "no-free-lunch" principle - recognize the necessity of compromise - appreciate the "cost" of actions and in-actions. 1 2 3 4 5

7.19 Understand the methodology of effective brainstorming. 1 2 3 4 5

7.20 Develop and/or utilize systematic problem solving techniques. 1 2 3 4 5

7.21 Work in a "team" environment that requires compromising for the "good of the whole." 1 2 3 4 5

7.22 Communicate effectively with other team members and ensure that your own work and team members work is completed on time. 1 2 3 4 5

7.23 Share workload and credits with the team. 1 2 3 4 5

7.24 Know how to "learn to learn" (life-long learning). 1 2 3 4 5

7.25 Recognize that the best solution meets the needs of all departments/operations (politically sensitive, but don't compromise to reach a poor implementation). 1 2 3 4 5

7.26 Develop a global (company) perspective. 1 2 3 4 5

7.27 Understand sexism, racism, and politics. 1 2 3 4 5

7.28 Understand the benefits of networking computing devices. 1 2 3 4 5

7.29 Understand post-manufacturing problems (solid waste). 1 2 3 4 5

7.30 Understand what is expected in safety and health. 1 2 3 4 5

7.31 Understand handling of hazardous chemicals. 1 2 3 4 5

7.32 Understand issues associated with the environment in the workplace. (Health and safety concerns) 1 2 3 4 5

7.33	Understand environmental interactions of manufacturing processes.	1 2 3 4 5
7.34	Understand what motivates employees.	1 2 3 4 5
7.35	Understand chemical applications and safety concerns.	1 2 3 4 5
7.36	Understand work place worker rights and responsibilities.	1 2 3 4 5

COMPETENCY 8 - CAPSTONE COURSES

Entry-level graduates with a B.S. Manufacturing Engineering Technology should be able to:

8.1	Demonstrate a work ethic that displays motivation, natural curiosity, and a sense of responsiveness without close supervision.	1 2 3 4 5
8.2	Learn to get the job done right, without any excuses, and on schedule with minimal supervision.	1 2 3 4 5
8.3	Maintain loyalty to the company and department - ensuring goals are met regardless of outside influences. (care about your company as if you owned it).	1 2 3 4 5
8.4	Balance personal and professional life.	1 2 3 4 5
8.5	Demonstrate personal ethics and be able to apply them.	1 2 3 4 5
8.6	Develop time management skills.	1 2 3 4 5
8.7	Assume authority and responsibility until someone stops you.	1 2 3 4 5
8.8	Expose yourself to your profession (conferences, seminars).	1 2 3 4 5
8.9	Integrate skills taught in various courses in an integrated project.	1 2 3 4 5
8.10	Demonstrate the ability to recognize problems in personal work environment/discuss practicality of solving them.	1 2 3 4 5
8.11	Resolve an unstructured problem.	1 2 3 4 5
8.12	Understand human psychology.	1 2 3 4 5
8.13	Demonstrate the ability to create time management plans, money, facilities budgets, and achievements for oneself.	1 2 3 4 5
8.14	Know how to learn new processes quickly.	1 2 3 4 5

ADDITIONAL COMPETENCIES REQUIRED AND THEIR IMPORTANCE

1. ______________________________ 1 2 3 4 5
2. ______________________________ 1 2 3 4 5
3. ______________________________ 1 2 3 4 5
4. ______________________________ 1 2 3 4 5
5. ______________________________ 1 2 3 4 5
6. ______________________________ 1 2 3 4 5
7. ______________________________ 1 2 3 4 5
8. ______________________________ 1 2 3 4 5
9. ______________________________ 1 2 3 4 5
10. ______________________________ 1 2 3 4 5
11. ______________________________ 1 2 3 4 5
12. ______________________________ 1 2 3 4 5

Lists of Qualified Jurors

Industrial Representation

Mr. Danny Crooke
Manufacturing Engineer
Outboard Marine Corporation
Andrews, NC 28751

Mr. Ron Westmoreland
Area Manufacturing Engineer
Outboard Marine Corporation
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Academic Representation

Dr. Jerry Cook
Professor Industrial & Engineering Technology
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Dr. Aaron Ball
Associate Professor Industrial & Engineering Technology
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Dr. Douglas Pine
Associate Professor Industrial Technology
University of Northern Iowa
Cedar Falls, IA 50613

Dr. Ali Kashef
Associate Professor Industrial Technology
University of Northern Iowa
Cedar Falls, IA 50613

APPENDIX C

MEANS, CORRELATION AND HYPOTHESIS FIGURES

Table C4

Mean Response of Competency Category per Company

Company No.	C1	C2	C3	C4	C5	C6	C7	C8	All
1	4.50	3.33	2.75	3.38	5.00	4.90	4.89	5.00	3.59
2	3.85	3.00	4.00	3.44	3.27	3.62	3.94	4.21	3.14
3	4.00	2.67	3.94	3.69	3.36	3.86	3.92	4.07	3.18
4	3.90	3.00	4.00	3.25	4.73	3.52	4.08	4.07	3.31
5	3.45	3.67	4.19	3.44	2.00	3.95	3.92	3.64	3.08
6	3.35	3.00	2.81	3.00	3.45	2.86	3.25	3.57	2.72
7	3.70	2.67	3.31	3.25	2.82	3.67	3.78	4.07	2.90
8	3.90	1.67	4.75	3.56	3.18	3.67	4.00	4.57	3.09
9	3.20	3.33	2.81	3.00	5.00	3.67	3.83	4.29	3.11
10	3.20	2.33	3.00	2.88	2.91	3.81	3.50	4.50	2.70
11	3.60	3.33	3.75	3.56	3.09	3.62	3.36	3.21	3.04
12	4.25	3.67	4.19	4.50	3.45	4.24	4.08	4.43	3.55
13	2.60	3.00	3.00	3.38	3.55	3.43	3.44	3.64	2.80
14	3.40	2.00	3.25	3.63	4.18	3.71	3.50	4.14	2.96
15	4.95	3.67	3.94	3.13	2.73	3.33	3.31	3.43	3.13
16	3.65	3.00	3.19	3.81	4.27	3.71	3.89	3.71	3.19
17	4.20	2.67	3.63	3.69	3.18	3.67	3.75	4.00	3.10
18	3.80	4.00	4.06	3.56	3.91	4.19	4.11	4.00	3.45
19	2.80	3.33	2.88	3.19	3.91	3.19	3.89	4.71	2.90
20	3.75	2.00	3.19	3.56	2.18	3.95	3.97	4.14	2.83
21	4.40	3.67	4.31	3.88	4.18	4.14	4.42	4.79	3.62
22	3.90	3.67	3.63	3.00	3.73	3.00	4.00	3.86	3.11
23	4.25	3.67	3.69	3.06	3.73	4.33	3.78	4.14	3.31
24	3.35	3.00	3.25	2.81	3.91	3.00	3.64	3.79	2.87
25	3.35	2.33	3.25	2.75	2.27	3.24	3.78	4.00	2.62
26	3.60	3.00	3.94	3.63	3.09	3.57	3.36	3.00	3.02
27	3.75	3.00	3.06	3.44	3.00	3.29	3.44	3.71	2.87
28	3.05	1.00	2.25	2.31	2.18	2.67	3.31	3.14	2.10

(Table Continues)

Company No.	C1	C2	C3	C4	C5	C6	C7	C8	All
29	3.25	4.00	3.44	3.63	2.18	3.52	3.56	4.14	2.95
30	4.20	3.67	4.13	3.00	3.82	3.57	4.28	4.00	3.33
31	4.05	2.33	3.50	3.75	3.18	4.00	3.78	3.86	3.07
32	4.85	4.00	3.88	4.31	2.45	4.24	5.00	5.00	3.59
33	5.00	4.00	4.44	4.00	4.00	4.00	4.36	4.00	3.72
34	4.20	2.33	3.00	3.38	2.27	3.95	4.36	4.43	2.90
35	4.20	3.00	3.56	3.44	3.82	4.24	4.14	4.57	3.30
36	3.75	3.33	3.88	3.31	3.00	3.86	3.75	4.00	3.11
37	4.00	3.00	3.25	3.69	2.09	3.48	3.69	4.21	2.90
38	4.30	2.67	3.75	4.44	4.91	4.33	4.31	4.07	3.59
39	3.60	2.00	3.00	3.63	2.55	3.29	4.22	4.64	2.78
40	4.50	3.00	3.31	3.88	3.09	3.90	3.89	4.29	3.20
41	4.00	3.33	3.38	2.56	3.00	2.95	3.17	3.14	2.80
42	3.10	2.67	3.44	3.31	3.09	3.43	3.78	3.93	2.85
43	3.80	2.67	3.31	3.44	2.27	3.19	3.14	3.43	2.73
44	3.00	1.67	2.81	2.81	2.00	2.86	3.00	3.00	2.27
45	3.90	2.67	3.75	3.44	3.00	3.33	4.03	4.29	3.01
46	3.60	1.67	3.31	2.81	2.27	3.00	3.53	3.86	2.52
47	4.40	2.33	4.13	2.69	1.64	3.48	3.50	3.00	2.77
48	4.20	3.00	3.63	4.25	3.82	4.10	4.94	5.00	3.49
49	4.35	3.00	3.50	3.50	3.82	3.86	4.50	4.29	3.32
50	3.20	1.33	2.63	3.31	3.91	3.76	3.75	3.64	2.74

Table C5
Plant Size Groupings and Mean Competency Categories.

Plant Size	Number Employees	C1	C2	C3	C4	C5	C6	C7	C8
Small	12	3.65	3.00	3.19	3.81	4.27	3.71	3.89	3.71
Small	25	4.40	2.33	4.13	2.69	1.64	3.48	3.50	3.00
Small	40	5.00	4.00	4.44	4.00	4.00	4.00	4.36	4.00
Small	60	4.20	3.00	3.63	4.25	3.82	4.10	4.94	5.00
Small	80	4.00	3.00	3.25	3.69	2.09	3.48	3.69	4.21
Small	110	3.85	3.00	4.00	3.44	3.27	3.62	3.94	4.21
Small	120	3.45	3.67	4.19	3.44	2.00	3.95	3.92	3.64
Small	140	2.60	3.00	3.00	3.38	3.55	3.43	3.44	3.64
Small	140	3.35	3.00	3.25	2.81	3.91	3.00	3.64	3.79
Small	140	4.20	3.67	4.13	3.00	3.82	3.57	4.28	4.00
Small	150	3.20	2.33	3.00	2.88	2.91	3.81	3.50	4.50
Small	150	4.20	2.67	3.63	3.69	3.18	3.67	3.75	4.00
Small	150	3.80	2.67	3.31	3.44	2.27	3.19	3.14	3.43
Small	150	3.20	1.33	2.63	3.31	3.91	3.76	3.75	3.64
Small	160	3.80	4.00	4.06	3.56	3.91	4.19	4.11	4.00
Small	160	4.40	3.67	4.31	3.88	4.18	4.14	4.42	4.79
Medium	170	2.80	3.33	2.88	3.19	3.91	3.19	3.89	4.71
Medium	180	3.05	1.00	2.25	2.31	2.18	2.67	3.31	3.14
Medium	200	4.25	3.67	3.69	3.06	3.73	4.33	3.78	4.14
Medium	200	4.20	2.33	3.00	3.38	2.27	3.95	4.06	4.43
Medium	200	4.00	3.33	3.38	2.56	3.00	2.95	3.17	3.14
Medium	200	3.10	2.67	3.44	3.31	3.09	3.43	3.78	3.93
Medium	236	3.75	3.33	3.88	3.31	3.00	3.86	3.75	4.00
Medium	240	4.05	2.33	3.50	3.75	3.18	4.00	3.78	3.86
Medium	250	4.25	3.67	4.19	4.50	3.45	4.24	4.08	4.43
Medium	250	3.00	1.67	2.81	2.81	2.00	2.86	3.00	3.00
Medium	265	3.90	1.67	4.75	3.56	3.18	3.67	4.00	4.57

(Table Continues)

Plant Size	Number Employees	C1	C2	C3	C4	C5	C6	C7	C8
Medium	300	3.90	3.00	4.00	3.25	4.73	3.52	4.08	4.07
Medium	300	3.60	3.00	3.94	3.63	3.09	3.57	3.36	3.00
Medium	300	3.75	3.00	3.06	3.44	3.00	3.29	3.44	3.71
Medium	350	4.00	2.67	3.94	3.69	3.36	3.86	3.92	4.07
Medium	350	3.90	2.67	3.75	3.44	3.00	3.33	4.03	4.29
Medium	350	3.60	1.67	3.31	2.81	2.27	3.00	3.53	3.86
Large	366	3.60	3.33	3.75	3.56	3.09	3.62	3.36	3.21
Large	379	4.85	4.00	3.88	4.31	2.45	4.24	5.00	5.00
Large	400	3.35	2.33	3.25	2.75	2.27	3.24	3.78	4.00
Large	450	3.40	2.00	3.25	3.63	4.18	3.71	3.50	4.14
Large	450	3.90	3.67	3.63	3.00	3.73	3.00	4.00	3.86
Large	450	3.25	4.00	3.44	3.63	2.18	3.52	3.56	4.14
Large	500	4.95	3.67	3.94	3.13	2.73	3.33	3.31	3.43
Large	500	4.50	3.00	3.31	3.88	3.09	3.90	3.89	4.29
Large	600	4.20	3.00	3.56	3.44	3.82	4.24	4.14	4.57
Large	700	3.35	3.00	2.81	3.00	3.45	2.86	3.25	3.57
Large	750	3.60	2.00	3.00	3.63	2.55	3.29	4.22	4.64
Large	850	4.30	2.67	3.75	4.44	4.91	4.33	4.31	4.07
Large	1000	3.75	2.00	3.19	3.56	2.18	3.95	3.97	4.14
Large	1800	4.35	3.00	3.50	3.50	3.82	3.86	4.50	4.29
Large	2000	4.50	3.33	2.75	3.38	5.00	4.90	4.89	5.00
Large	2200	3.70	2.67	3.31	3.25	2.82	3.67	3.78	4.07
Large	2200	3.20	3.33	2.81	3.00	5.00	3.67	3.83	4.29

Table C6
Plant location and Mean Competency Category
Response per Company

Company No.	Plant Loc.	C1	C2	C3	C4	C5	C6	C7	C8	Mean
1	1	4.50	3.33	2.75	3.38	5.00	4.90	4.89	5.00	3.59
2	1	3.85	3.00	4.00	3.44	3.27	3.62	3.94	4.21	3.14
3	0	4.00	2.67	3.94	3.69	3.36	3.86	3.92	4.07	3.18
4	1	3.90	3.00	4.00	3.25	4.73	3.52	4.08	4.07	3.31
5	1	3.45	3.67	4.19	3.44	2.00	3.95	3.92	3.64	3.08
6	1	3.35	3.00	2.81	3.00	3.45	2.86	3.25	3.57	2.72
7	0	3.70	2.67	3.31	3.25	2.82	3.67	3.78	4.07	2.90
8	0	3.90	1.67	4.75	3.56	3.18	3.67	4.00	4.57	3.09
9	1	3.20	3.33	2.81	3.00	5.00	3.67	3.83	4.29	3.11
10	1	3.20	2.33	3.00	2.88	2.91	3.81	3.50	4.50	2.70
11	0	3.60	3.33	3.75	3.56	3.09	3.62	3.36	3.21	3.04
12	1	4.25	3.67	4.19	4.50	3.45	4.24	4.08	4.43	3.55
13	0	2.60	3.00	3.00	3.38	3.55	3.43	3.44	3.64	2.80
14	1	3.40	2.00	3.25	3.63	4.18	3.71	3.50	4.14	2.96
15	0	4.95	3.67	3.94	3.13	2.73	3.33	3.31	3.43	3.13
16	0	3.65	3.00	3.19	3.81	4.27	3.71	3.89	3.71	3.19
17	1	4.20	2.67	3.63	3.69	3.18	3.67	3.75	4.00	3.10
18	0	3.80	4.00	4.06	3.56	3.91	4.19	4.11	4.00	3.45
19	0	2.80	3.33	2.88	3.19	3.91	3.19	3.89	4.71	2.90
20	1	3.75	2.00	3.19	3.56	2.18	3.95	3.97	4.14	2.83
21	1	4.40	3.67	4.31	3.88	4.18	4.14	4.42	4.79	3.62
22	1	3.90	3.67	3.63	3.00	3.73	3.00	4.00	3.86	3.11
23	0	4.25	3.67	3.69	3.06	3.73	4.33	3.78	4.14	3.31
24	1	3.35	3.00	3.25	2.81	3.91	3.00	3.64	3.79	2.87
25	1	3.35	2.33	3.25	2.75	2.27	3.24	3.78	4.00	2.62
26	1	3.60	3.00	3.94	3.63	3.09	3.57	3.36	3.00	3.02
27	1	3.75	3.00	3.06	3.44	3.00	3.29	3.44	3.71	2.87
28	0	3.05	1.00	2.25	2.31	2.18	2.67	3.31	3.14	2.10

(Table Continues)

Company No.	Plant Loc.	C1	C2	C3	C4	C5	C6	C7	C8	Mean
29	0	3.25	4.00	3.44	3.63	2.18	3.52	3.56	4.14	2.95
30	1	4.20	3.67	4.13	3.00	3.82	3.57	4.28	4.00	3.33
31	1	4.05	2.33	3.50	3.75	3.18	4.00	3.78	3.86	3.07
32	1	4.85	4.00	3.88	4.31	2.45	4.24	5.00	5.00	3.59
33	0	5.00	4.00	4.44	4.00	4.00	4.00	4.36	4.00	3.72
34	1	4.20	2.33	3.00	3.38	2.27	3.95	4.06	4.43	2.90
35	1	4.20	3.00	3.56	3.44	3.82	4.24	4.14	4.57	3.30
36	1	3.75	3.33	3.88	3.31	3.00	3.86	3.75	4.00	3.11
37	0	4.00	3.00	3.25	3.69	2.09	3.48	3.69	4.21	2.90
38	0	4.30	2.67	3.75	4.44	4.91	4.33	4.31	4.07	3.59
39	1	3.60	2.00	3.00	3.63	2.55	3.29	4.22	4.64	2.78
40	0	4.50	3.00	3.31	3.88	3.09	3.90	3.89	4.29	3.20
41	1	4.00	3.33	3.38	2.56	3.00	2.95	3.17	3.14	2.80
42	0	3.10	2.67	3.44	3.31	3.09	3.43	3.78	3.93	2.85
43	0	3.80	2.67	3.31	3.44	2.27	3.19	3.14	3.43	2.73
44	0	3.00	1.67	2.81	2.81	2.00	2.86	3.00	3.00	2.27
45	1	3.90	2.67	3.75	3.44	3.00	3.33	4.03	4.29	3.01
46	1	3.60	1.67	3.31	2.81	2.27	3.00	3.53	3.86	2.52
47	1	4.40	2.33	4.13	2.69	1.64	3.48	3.50	3.00	2.77
48	1	4.20	3.00	3.63	4.25	3.82	4.10	4.94	5.00	3.49
49	0	4.35	3.00	3.50	3.50	3.82	3.86	4.50	4.29	3.32
50	0	3.20	1.33	2.63	3.31	3.91	3.76	3.75	3.64	2.74

Note. 1 = Rural, 0 = Urban

Table C7
Plant location and Mean Competency Category Response per Company

Company No.	Plant Location	Mean Response All Competencies
1	1	4.39
2	1	3.78
4	1	3.89
5	1	3.64
6	1	3.17
9	1	3.63
10	1	3.40
12	1	4.17
14	1	3.59
17	1	3.74
20	1	3.63
21	1	4.30
22	1	3.63
24	1	3.38
25	1	3.75
26	1	3.46
27	1	3.40
30	1	3.91
31	1	3.74
32	1	4.42
34	1	3.72
35	1	4.01
36	1	3.69
39	1	3.64
41	1	3.20
45	1	3.72
46	1	3.24
47	1	3.38

(Table Continues)

Company No.	Plant Location	Mean Response All Competencies
48	1	4.34
3	0	3.84
7	0	3.56
8	0	3.91
11	0	3.47
13	0	3.28
15	0	3.58
16	0	3.73
18	0	4.18
19	0	3.50
23	0	3.87
28	0	2.77
29	0	3.46
33	0	4.29
37	0	3.56
38	0	4.25
40	0	3.87
42	0	3.47
43	0	3.25
44	0	2.82
49	0	4.04
50	0	3.44

Note. 1 = Rural, 0 = Urban

Figure C1
Scatter Diagram Competency 1, Design for Production vs
Number of Manufacturing Technologies Used

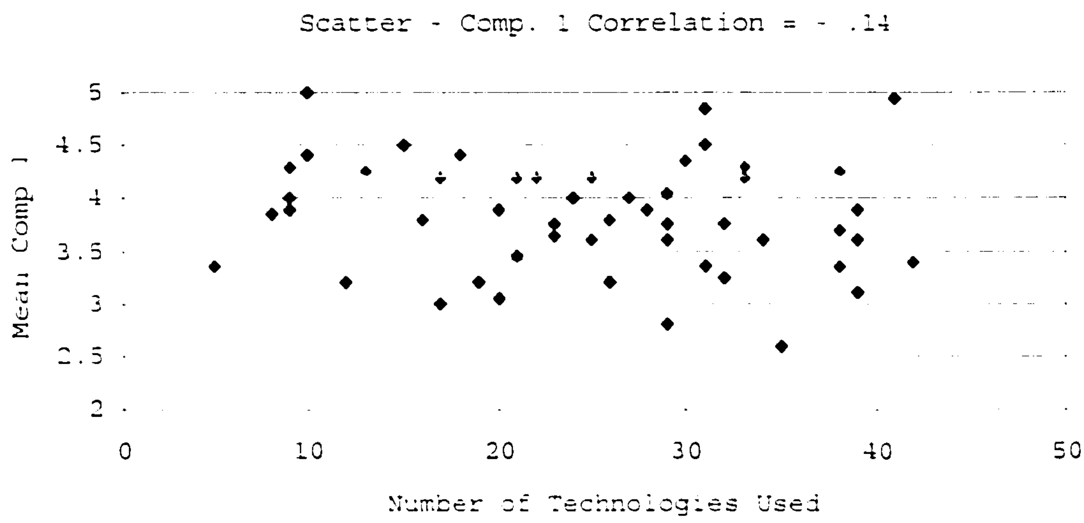

Figure C2
Scatter Diagram Competency 2, Materials vs
Number of Manufacturing Technologies Used

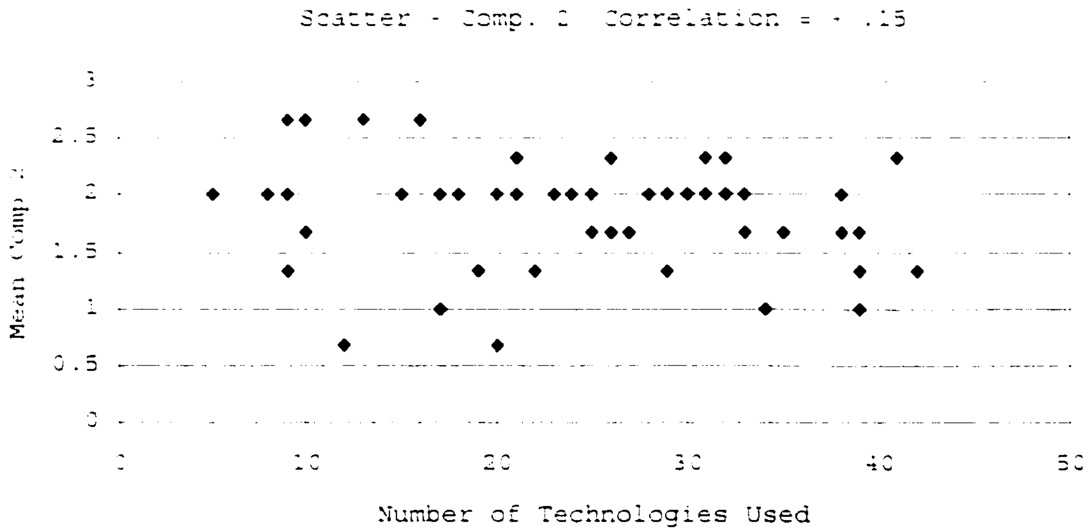

Figure C3
Scatter Diagram Competency 3, Manufacturing Processes vs Number of Manufacturing Technologies Used

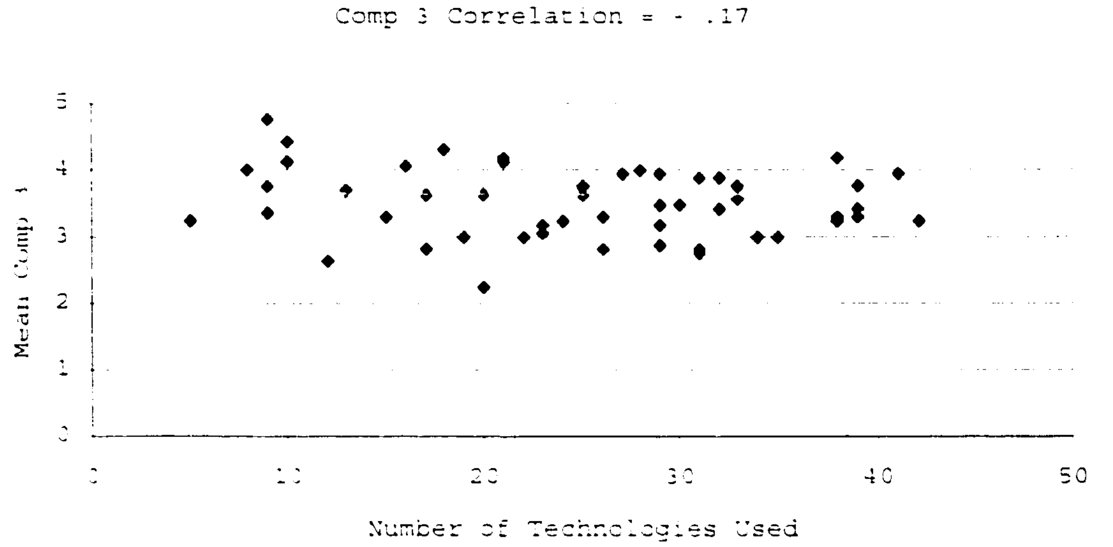

Figure C4
Scatter Diagram Competency 4, Manufacturing Systems and Automation vs Number of Manufacturing Technologies Used

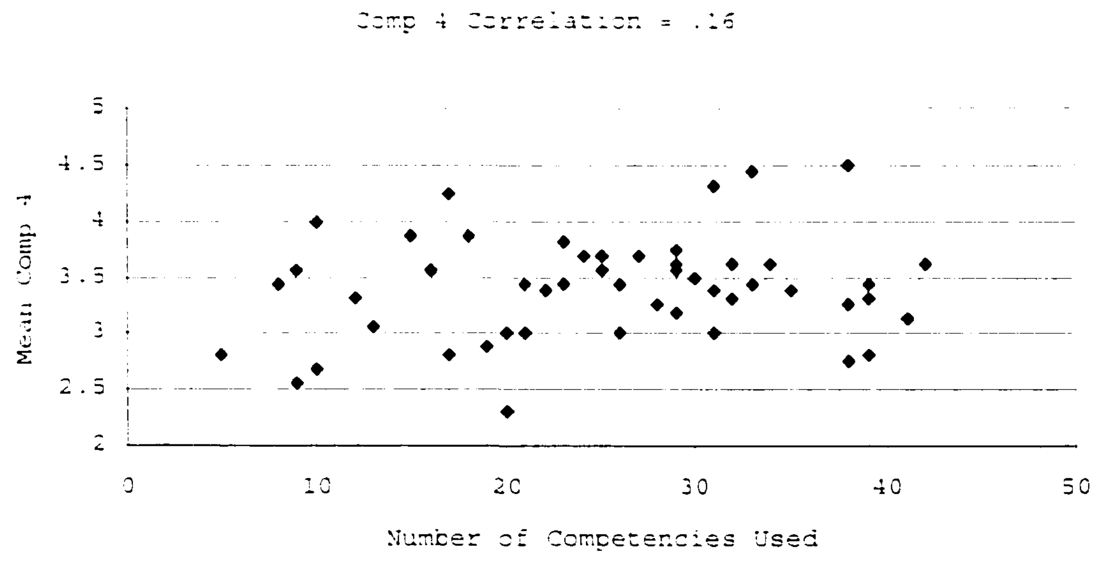

Figure C5
Scatter Diagram Competency 5, Controls vs Number of Manufacturing Technologies Used

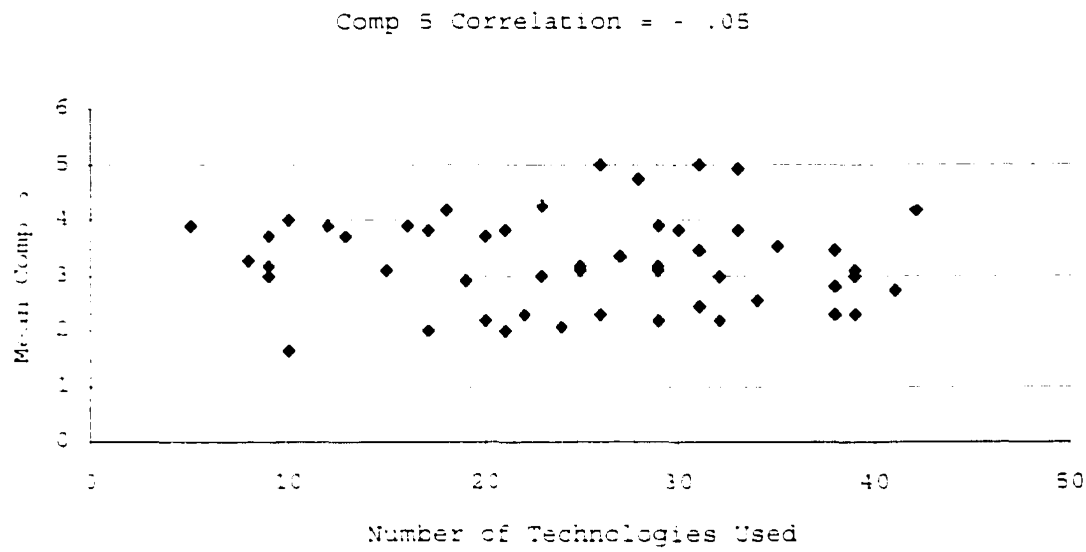

Figure C6
Scatter Diagram Competency 6, Manufacturing Management/Quality & Productivity vs Number of Manufacturing Technologies Used

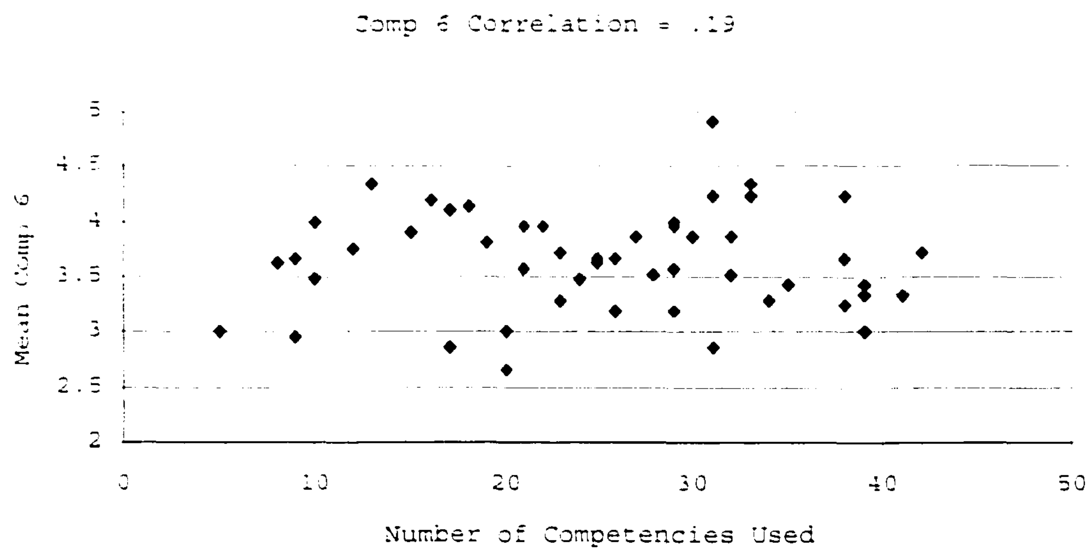

Figure C7
Scatter Diagram Competency 7, Liberal Studies vs
Number of Manufacturing Technologies Used

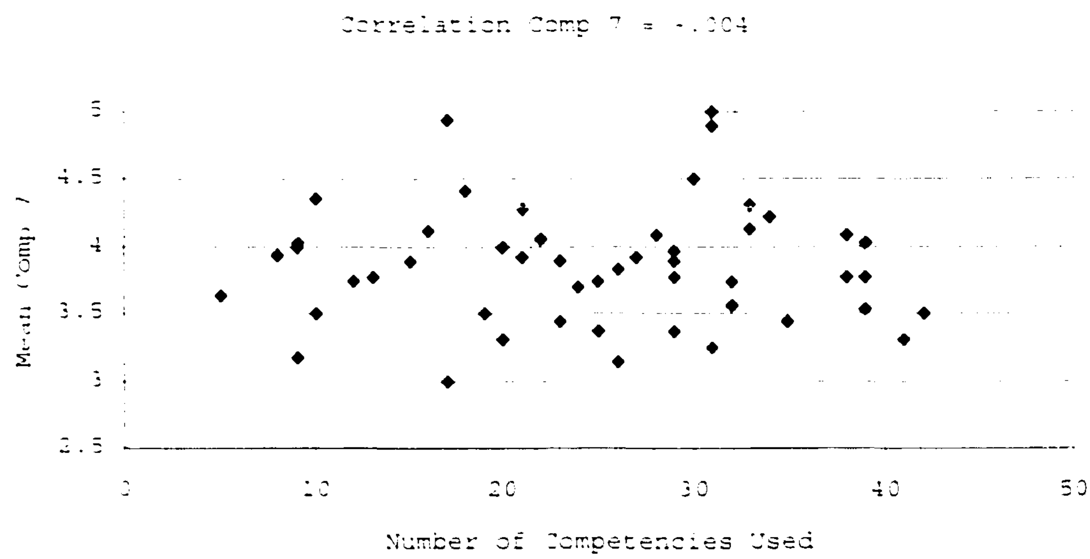

Figure C8
Scatter Diagram Competency 8, Capstone Courses vs
Number of Manufacturing Technologies Used

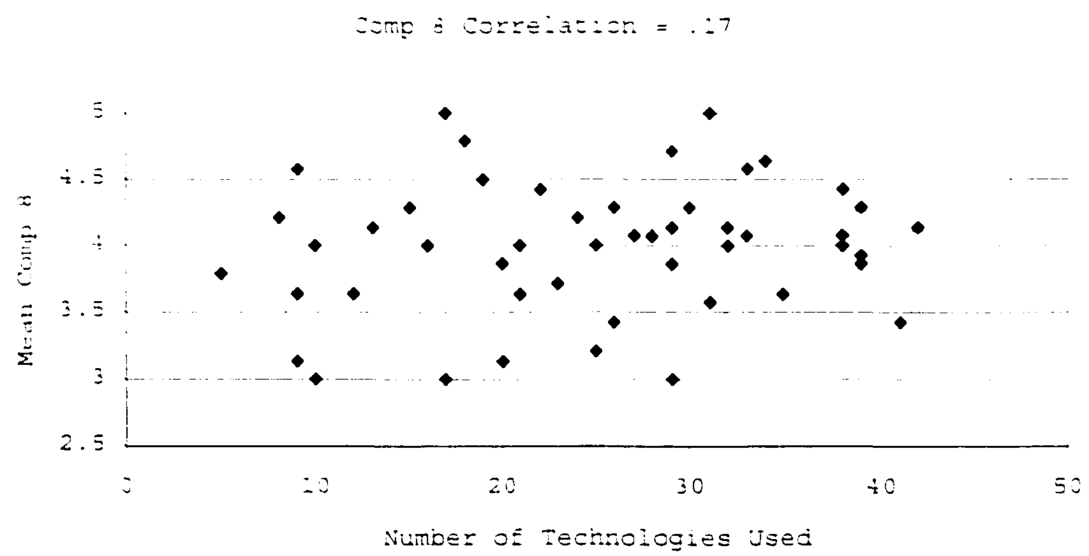

Figure C9
Normal Probability and Standardized Residuals
Competency 1, Design for Production

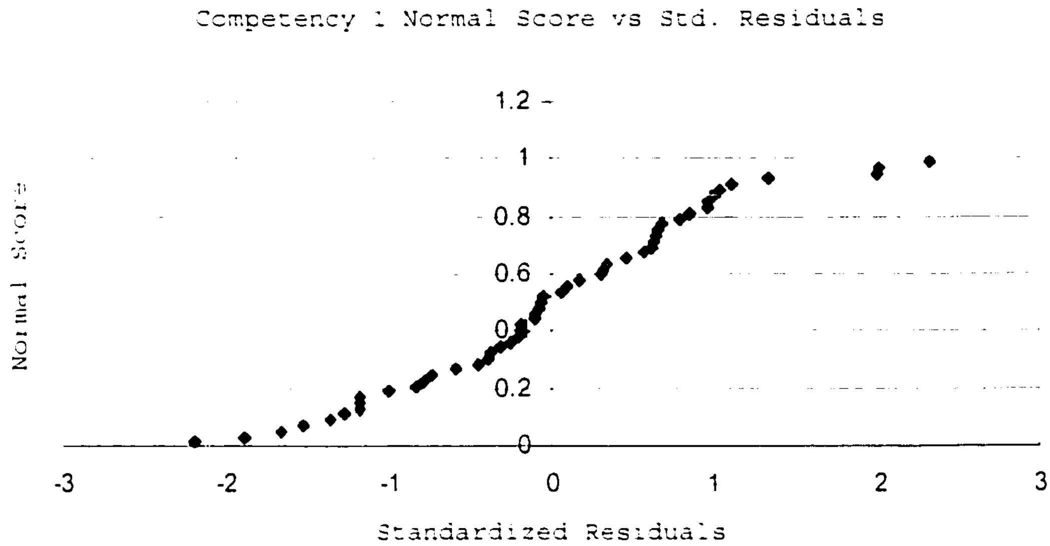

Figure C10
Normal Probability and Standardized Residuals
Competency 2, Materials

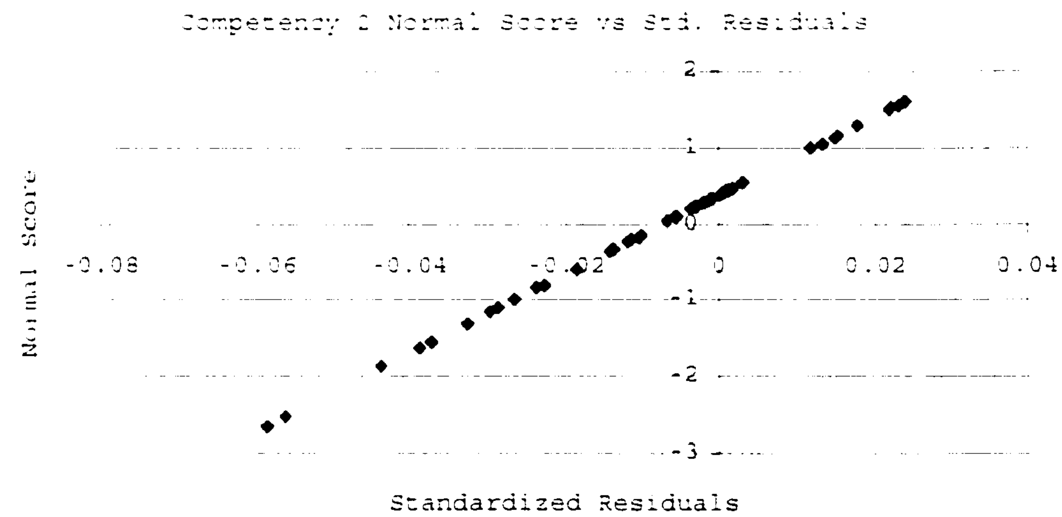

Figure C11
Normal Probability and Standardized Residuals
Competency 3, Manufacturing Processes

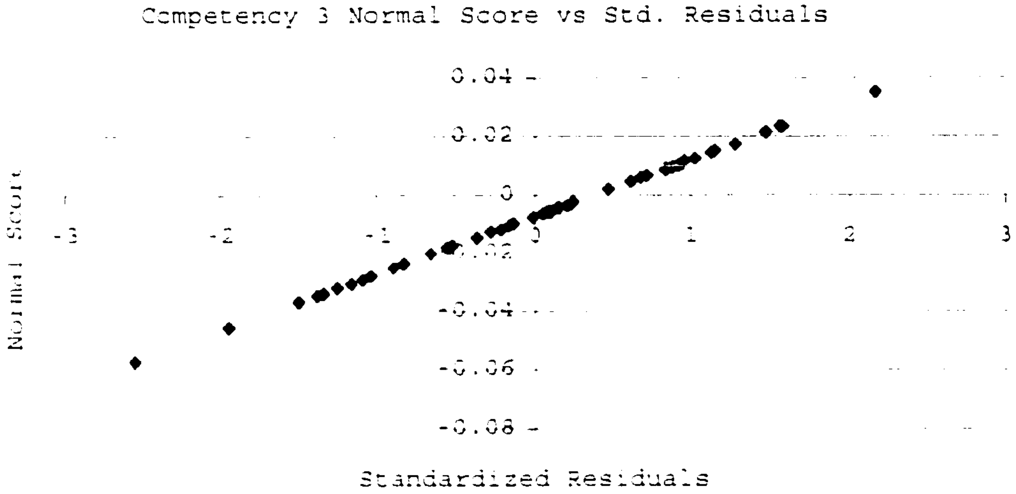

Figure C12
Normal Probability and Standardized Residuals
Competency 4, Manufacturing Systems & Automation

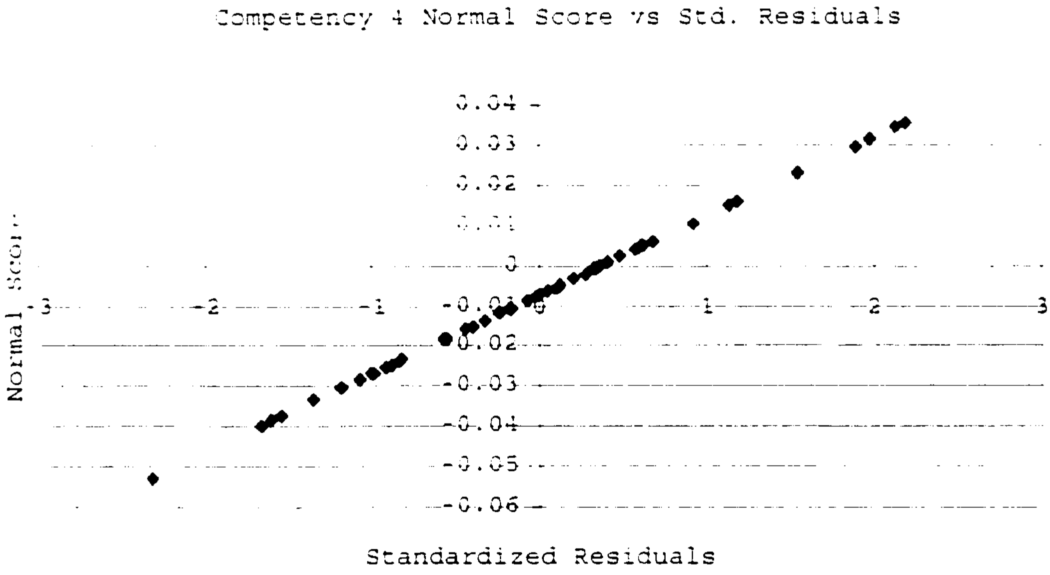

Figure C13
Normal Probability and Standardized Residuals
Competency 5, Controls

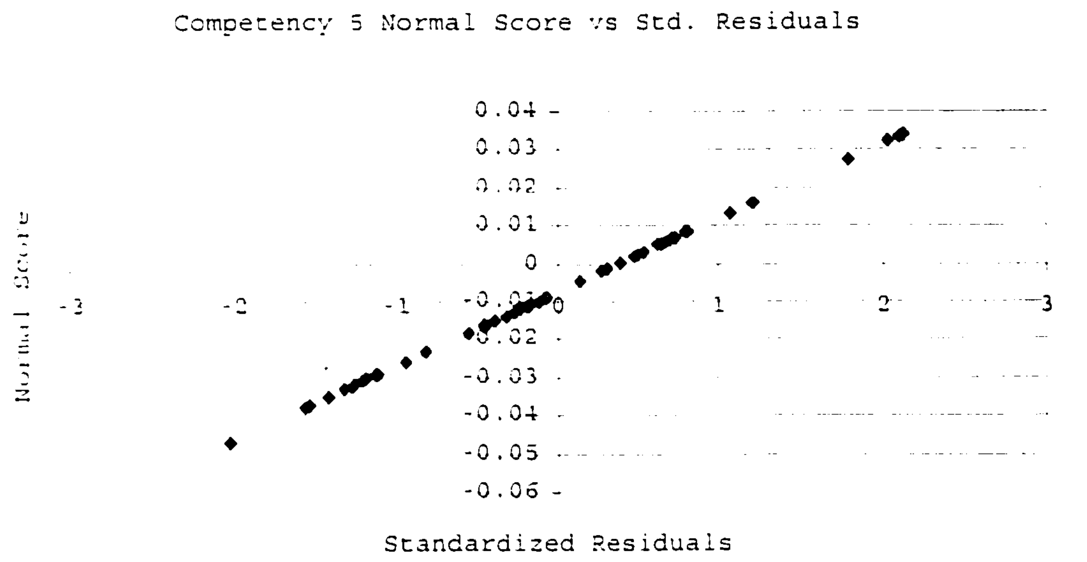

Figure C14
Normal Probability and Standardized Residuals
Competency 6, Manufacturing Mgt./Quality & Productivity

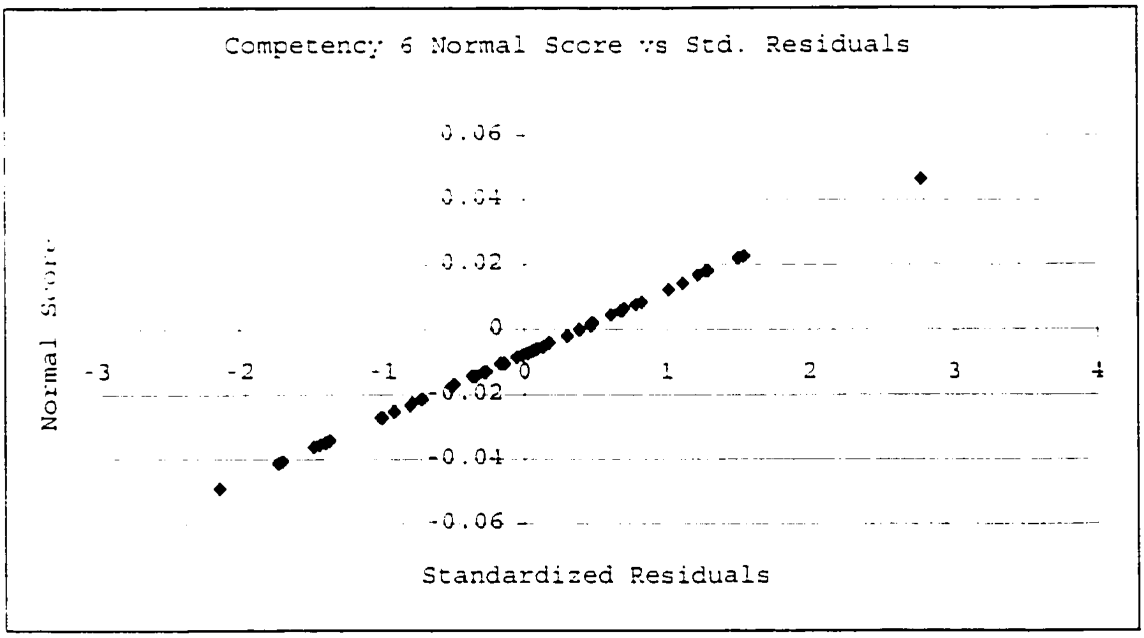

Figure C15
Normal Probability and Standardized Residuals
Competency 7, Liberal Studies

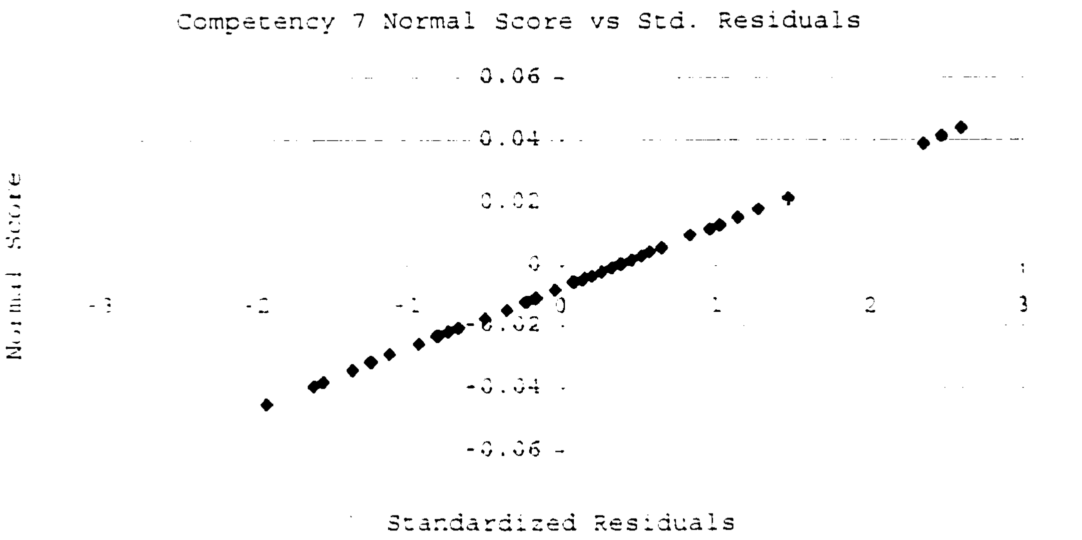

Figure C16
Normal Probability and Standardized Residuals
Competency 8, Capstone Courses

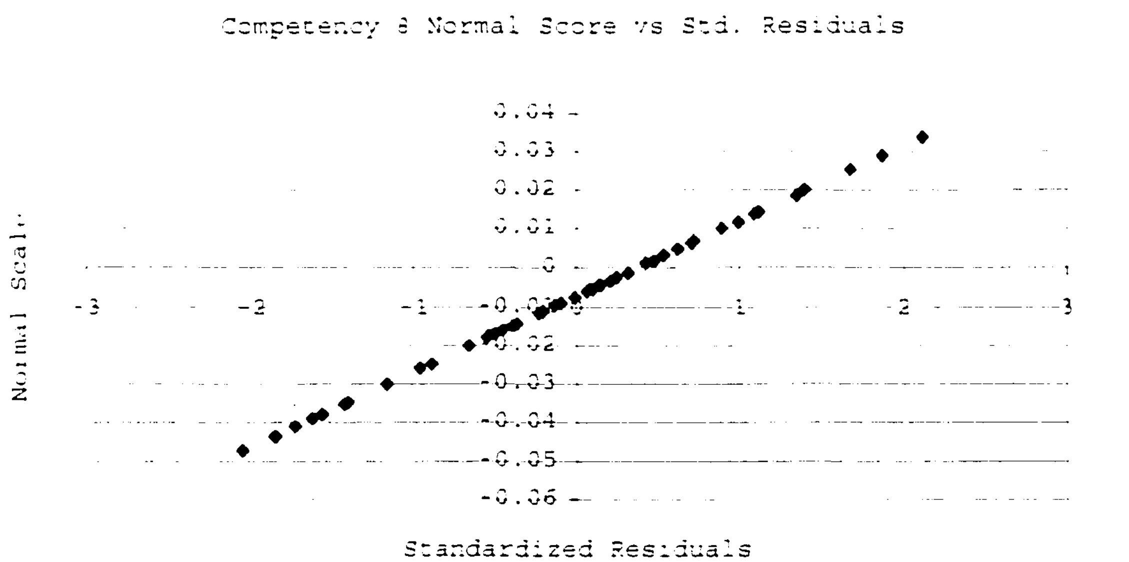

Figure C17
Scatter Diagram Competency 3, Plant Size Large, Capstone Courses vs Number of Manufacturing Technologies Used

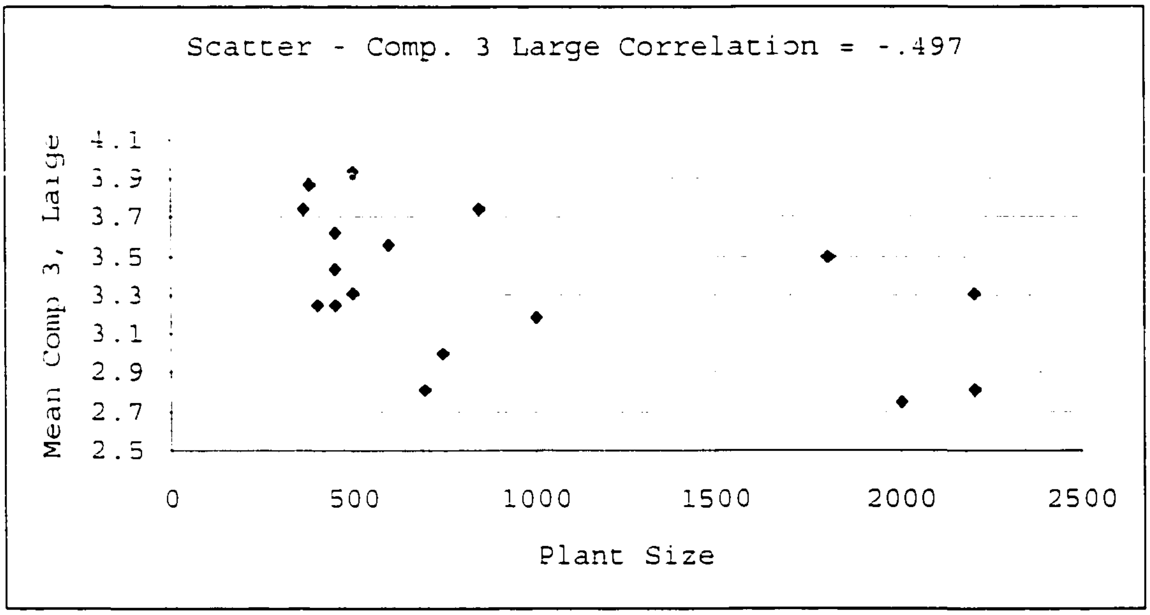

Figure C18
Scatter Diagram Competency 5, Plant Size Large, Capstone Courses vs Number of Manufacturing Technologies Used

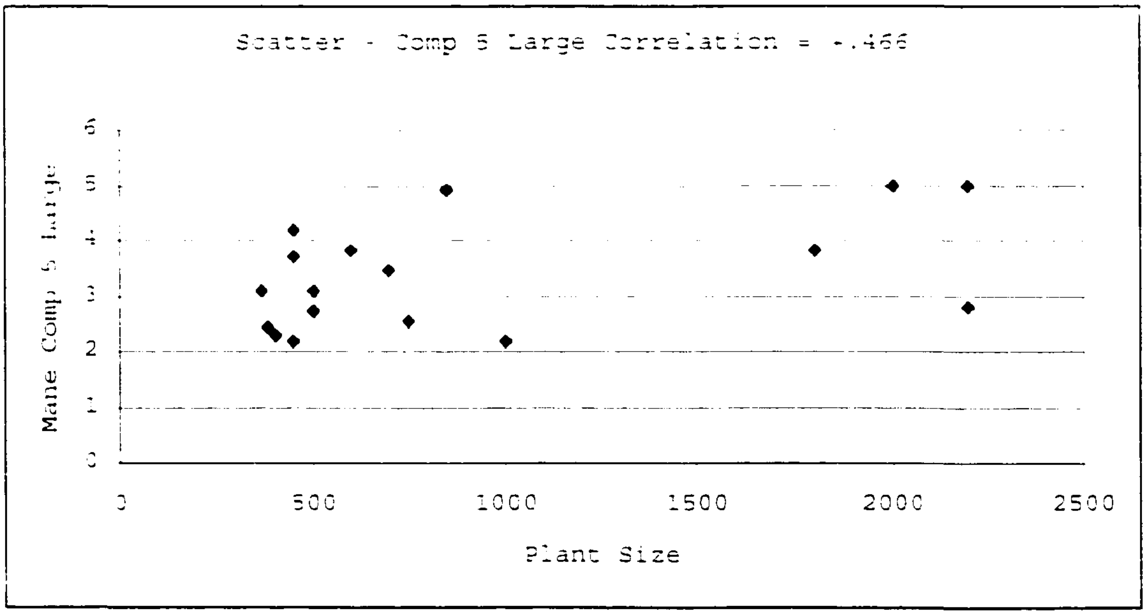

Figure C19
Scatter Diagram Competency 3, Plant Size Medium, Capstone Courses vs Number of Manufacturing Technologies Used