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## *Introduction*

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 and regional industries. Thus there is a need to establish local and regional criteria for manufacturing competencies. A review of literature validates a set of manufacturing competencies required of entry-level graduates but does not address the industrial education needs according to the demographic needs of industry. To better understand the affect of demographic variables on manufacturing competencies and to better equip manufacturing educators on curricula content specific to their service areas. This study attempted to identify relationships between manufacturing demographics and established competencies for manufacturing programs in the state of North Carolina.

## *Rationale*

The need for examining the relationship between manufacturing competencies and regional demographics results from several economic and industrial changes. 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. 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 workers (Harris Info, 1999). 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).

The utilization spectrum of manufacturing technologies and thus the on the job competency requirements of industrial and manufacturing technology graduates vary. 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 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 influenced by plant size. Knudsen research shows that 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. Thus in certain states, the utilization of manufacturing technologies vary per plant size.

## *Purpose*

The purpose of this study was to assist manufacturing educators involved with curriculum development, workforce development, and technology transfer by identifying competency correlation according to selected manufacturing demographics of plant size, plant location, and usage of manufacturing technologies.

## Research Questions

The following research questions are designed to address correlation between facility demographics of plant size, location, and usage of manufacturing technologies to the importance of manufacturing competencies.

1) Is there significant correlation between the number of employees at the work site (plant size) respondents and each competency category?
2) Is there significant correlation between plant location and each competency category?
3) Is there significant correlation between the degree of usage of manufacturing technologies and each competency category?

## Methodology

Collected data from practicing manufacturing engineers in manufacturing industries on the perceived importance of entry-level manufacturing competencies were evaluated against number of employees, plant location, and usage of manufacturing technologies. Data were analyzed using correlation analysis. Each manufacturing engineer was asked to provide information on his or her company demographics. The independent variables were number of employees, plant location (urban or rural), and degree of usage of manufacturing technologies. The dependent variables were the respondent's rating (minimally important to extremely important) of the previously validated manufacturing competencies. A partial list of competencies within each major category is listed in table 1. Respondents were asked to indicate their plant's usage of a spectrum of manufacturing technologies. Table 2 shows the list of manufacturing technologies from which respondents selected as in-use or under development at their facility. Respondents' count of usage of technology was compared against each competency category.

***Table 1. Annotated Manufacturing Competencies List Per Category***

| | | |
|---|---|---|
| Design for Production | | |
| 1.0 | Read and interpret assembly drawings. | 1 2 3 4 5 |
| 1.1 | Understand geometric dimensioning and tolerancing. | 1 2 3 4 5 |
| Materials | | |
| 2.0 | Select the proper tooling and parameters for machining operations (metals), (know how to make a part). | 1 2 3 4 5 |
| 2.1 | Understand the injection molding process and related plastics applications. (know how to make a part). | 1 2 3 4 5 |
| Manufacturing Processes | | |
| 3.0 | Understand basic machining operations and equipment. | 1 2 3 4 5 |
| 3.1 | 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 |
| Manufacturing Systems and Automation | | |
| 4.0 | Identify and eliminate non-value added operations. | 1 2 3 4 5 |
| 4.1 | Apply knowledge of a wide variety of manufacturing processes | 1 2 3 4 5 |
| Controls | | |
| 5.0 | Integrate off the shelf control equipment into new and existing manufacturing operations. | 1 2 3 4 5 |
| 5.1 | Verify that installed control equipment operates correctly. | 1 2 3 4 5 |
| Manufacturing Management / Quality and Productivity | | |
| 6.0 | Understand the importance of quality – the importance of doing it right the first time. | 1 2 3 4 5 |
| 6.1 | Analyze the nature of parts rejection to determine the cause and devise | 1 2 3 4 5 |
| Liberal Studies | | |
| 7.0 | Communicate oral and written messages in a clear, concise, and professional manner. | 1 2 3 4 5 |
| 7.1 | Prepare technical reports. | 1 2 3 4 5 |
| Capstone Courses | | |
| 8.0 | Demonstrate a work ethic that displays motivation, natural curiosity, and a sense of responsiveness without close supervision. | 1 2 3 4 5 |
| 8.1 | Learn to get the job done right, without any excuses, and on schedule with minimal supervision. | 1 2 3 4 5 |

## *Analysis*

Research question one asked if there is a significant relationship between the number of employees and each manufacturing competency category. Each competency category was investigated using Pearson's correlation. Table 3 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. Three correlations were significant using one tail testing. Large plant sizes indicated competencies three and five 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.

Research question two seeks to determine if the urban and rural location of a plant has any effect on the importance of each manufacturing competency category. Point–biserial correlation was used to determine the significance of this variable. Table 4 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) = .279, $p < .05$, two tail.

Research question three 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. Table 5 points toward a positive correlation on competencies categories 4, 6 and 8 and negative correlation on competencies 1,2,3,5,and 7. However, the effect is not significant on all competencies at $r$(49) = .273, $p < .05$, two tail. 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

***Table 2. Utilization Spectrum of Manufacturing Technologies***

<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. (i.e., 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

<u>Product Design Capabilities</u>

_____ Manual Drafting
_____ 2-D Drafting - i.e. 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

<u>Management</u>

_____ 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

<u>Machining</u>

_____ 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.

that correlation between usage of technology and individual manufacturing competency categories does not appear to occur in the population.

## Impact on Students

Placement is of high concern to students upon graduation. Although results were significant in some competencies categories, adjusting the curriculum for local and regional needs has both positive and negative impact on a student's chance of getting a job. When local or regional skills are taught in terms of specific machining and design software, national trends are ignored. Many CAD positions call for knowledge of specific design software. The same is true for machining and automation software. If a student is interested in staying a region, then the utilization of locally used software is desired and gives students a placement advantage. Often universities have "feeder" companies in their region where students are employed upon graduation. Certainly teaching skill sets more specific to these companies would be an advantage to students and to the university in terms of advisory boards, senior projects, and funding. However, as mentioned in the opening paragraph, some local industry do not have or cannot afford large capital equipment cost for modern technology, thus a localized tailoring of the curriculum would be "dumbing down" student skills rather than being a leader in technology areas. For national placement of students, a broader national skills set should be developed. If the role of regional universities is to serve regional industry, and if students are interested in living the in area where they grew up then, adjusting the curriculum according to regional needs is advantageous.

## Summary

This study showed a one tailed negative correlation between large plant size and the importance of manufacturing competency category "manufacturing processes" and a one tailed positive correlation between medium plant size and manufacturing competency category "controls". As agents of technology transfer to regional industries, regional universities should strive

***Table 2. Utilization Spectrum of Manufacturing Technologies (continued)***

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 Protocols.
_____ 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

***Table 3. Correlation Each Competency Category Grouped S, M, L, and Plant Size***

| Competency Number | Competency | Small | Pearson *r* 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

to be leaders in the application advanced manufacturing technologies and management methods according to the needs of their industrial constituents. Elements of manufacturing curriculum should be somewhat tailored to the local and regional needs of industry.

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***Table 4. 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. $r_{pb}(48) = .279$, $p < .05$, two tail

***Table 5. 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