The relationship between competencies learned in Manufacturing Engineering programs and competencies represented in the CASA/SME Enterprise Wheel Model

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Abstract

This paper presents a comparison of what manufacturing engineering programs are teaching and what industry expects manufacturing engineers to know, as presented by the CASA/SME Manufacturing Enterprise Wheel. This comparison suggests that manufacturing engineering programs should encompass a broader scope of

engineering, technology, and management, and work to integrate content and projects across the curriculum.

Keywords

Manufacturing engineering, manufacturing education, manufacturing curriculum, and manufacturing enterprise wheel.

1 INTRODUCTION

The emergence of new technology during the past decade has revolutionized the manufacturing industry. However, in order to be more competitive in the global market a knowledgeable and technically competent workforce is also needed. Engineering education programs should reflect the needs and changes of today's industry and prepare young engineers to meet the challenges of the competitive world of manufacturing. Industry needs engineers who have the understanding of basic manufacturing engineering theory and the ability to apply knowledge that is relevant to the real world of manufacturing. Moreover, companies need individuals who have expertise in their field of specialty and who have knowledge and understanding of the integrated manufacturing environment. As such, there is a need for a comparison between the competencies required by industry today and the competencies learned in manufacturing engineering programs.

2 PURPOSE

The purpose of this paper is to report on the relationship between the competencies represented by the new Computer and Automated Systems Association of the Society of Manufacturing Engineers (CASA/SME) enterprise integration wheel model and the competencies learned in manufacturing engineering programs. There have been major changes in manufacturing in the United States and globally, and these changes have been reflected in the new CASA/SME enterprise model. Furthermore, these changes should be accommodated in existing manufacturing engineering programs.

3 DEFINITION OF ENGINEERING

According to the American Society for Engineering Education (1993b) and the Engineering Technology Council (1991), engineering involves the knowledge of advanced mathematical and natural sciences, and is devoted to the creation of new technology for the benefit of humanity. In addition, engineering is defined by the Accreditation Board for Engineering and Technology (ABET) as:

"A profession in which knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials

and forces of nature for the benefit of mankind" (Accreditation Board for Engineering and Technology, 1993b, p. 5).

Walker (1961) stated that "engineering is fundamentally committed to the translation of scientific facts and information to create machines, structures, materials, processes, [systems] and the like that can be used . . ." Furthermore, The engineer creates new products, devices, structures, materials, processes, and systems through the use of science, mathematics, and engineering science (Duderstadt, Knoll, and Springer, 1982).

4 GOALS OF ENGINEERING EDUCATION

The goals of undergraduate engineering education is to provide a base and a means for life-long learning rather than only to prepare a person as a specialist to perform a particular function in a particular industry. The following objectives were identified for undergraduate engineering curricula:

- “1. To provide an understanding of fundamental scientific principles and a command of basic knowledge underlying the student's field.
2. To convey an understanding of engineering methods such as analysis and computation, modeling, design and experimental verification, as well as experience in applying these methods to realistic engineering problems and processes.
3. To provide the student with the following:
 - a. An understanding of social and economic forces and their relationship with engineering systems, including the idea that the best technical solution may not be feasible when viewed in its social, political, or legal context;
 - b. A sense of professional responsibility developed through consideration of moral, ethical, and philosophical concepts; and
 - c. Mastering of the ability to organize and express ideas logically and persuasively in both written and oral communication.” (Engineering Undergraduate Education, 1986, pp. 9-10)

5 ENGINEERING PROGRAMS

A review of the literature reveals that programs offered under engineering are very diverse in scope and emphasis. According to the Directory of Engineering and Engineering Technology published by ASEE in 1994, a total of 1442 engineering

baccalaureate programs were accredited by the EAC/ABET. Moreover, 13 of those programs are in the area of manufacturing engineering.

The basic engineering education curricular components are mathematics, basic sciences, humanities, social sciences, engineering sciences, engineering design methods, and an engineering specialty. Thus, the content of engineering programs must be integrated in such a way that it will enable a graduate to function as an engineer (Accreditation Board for Engineering and Technology, 1993a).

6 CAREERS IN ENGINEERING

The graduates of engineering programs hold many different industrial positions with many of them being related to their undergraduate area of specialization, such as: automotive engineer, civil engineer, computer engineer, construction engineer, electrical engineer, industrial engineer, mechanical engineer, nuclear engineer, plant engineer, structural engineer, systems engineer, etc. In addition, research and development units are usually supervised and managed by engineers. According to Israel (1995) "engineers may also manage different divisions or units of a company and they hold management positions in such areas as computer-aided design, computer aided manufacturing, inventory control, manufacturing, production, process design, product design, quality control, systems, and technical sales."

Figure 1 represents the historical interfacing of the engineers in the occupational and educational spectrum (Lahidji, 1996).

Figure 1 The placement of engineers in the occupational and educational spectrum.

7 MANUFACTURING ENGINEERING

Based on the ABET Accreditation Yearbook (1996), there are 13 manufacturing engineering programs at the baccalaureate degree level which are accredited by ABET. In addition, according to SME's Directory of Manufacturing Education (1993) there are approximately 70 engineering programs that offer manufacturing engineering as an option. In the Directory of Manufacturing Education (1990, p.3) SME defined manufacturing engineering as:

“that specialty of professional engineering which requires such education and experience as is necessary to understand, apply and control engineering procedures in manufacturing processes and methods of production of industrial commodities and products and requires the ability to plan the practices of manufacturing, to research and develop the tools, processes, machines and equipment, and to integrate the facilities and systems for producing quality products with optimal expenditures.”

Furthermore, SME (1997) suggested that the graduates of manufacturing engineering curriculum must be proficient in the following areas:

- “1. Materials and manufacturing processes: understanding the behavior and properties of materials as they are altered and influenced by processing in manufacturing.
2. Process, assembly, and product engineering: understanding the design of products and the equipment, tooling, and environment necessary for their manufacturing.
3. Manufacturing competitiveness: understanding the creation of competitive advantage through manufacturing planning, strategy and control.
4. Manufacturing systems design: understanding the analysis, synthesis, and control of manufacturing operations using statistical and calculus-based methods.
5. Graduates must be able to measure manufacturing process variables in a manufacturing laboratory and make technical inferences about the process.”

The traditional role of a manufacturing engineer is changing from functioning in a segregated fashion to a more integrated one. They are more and more involved in the coordination of people, information, and technology within an organization. SME's Profile 21 (1988) study brought to light the more integrative role of today's manufacturing engineers.

8 MANUFACTURING ENTERPRISE WHEEL

The Computer and Automated Systems Association (CASA) of the Society of Manufacturing Engineers (SME) developed the CIM Wheel in 1985, which was received enthusiastically by both the membership of SME and industry (CASA, 1993). The CIM Wheel represented a new manufacturing environment and focused on a computer information system architecture for the integration of manufacturing automation. The 1985 CIM Wheel included the following five major components:

1. General business management,
2. Product and process definition,
3. Manufacturing planning and control,
4. Factory automation, and
5. Information resources management.

At the same time that U.S. manufacturing companies were implementing CIM into their operations, they were out-performed by a number of manufacturers who were adapting a new and very different approach, called lean/agile production (Womack, Jones, and Roos, 1991). They identified the superiority of the lean production system over conventional mass production systems in the following areas:

1. Higher productivity (both in space and per employee),
2. Higher profitability,
3. Higher product quality,
4. Cooperative industrial relations,
5. Cross-training,
6. Multi-skilled employee development,
7. Job rotation, and
8. Greater worker satisfaction.

In addition, Rehder (1990) in the article entitled "Japanese Transplant: After the Honeymoon" identified the following elements as being unique to a lean production system:

1. Employee empowerment,
2. Greater responsibility,
3. Teamwork,
4. Lateral communication,

5. Continuous improvement,
6. Multi-skilled employees,
7. Commitment to training (on-going training),
8. Job security,
9. Reduction of job classifications, and
10. Workers involvement in the specification of work methods.

Recently, the Boeing Company (ASEE PRISM, 1996, p.11) identified a list of desired attributes of engineering graduates. The list included the following factors.

1. A good understanding of the engineering fundamentals, including:
Mathematics(including statistics),
Physical and life sciences, and
Information technology.
2. A good grasp of the design and manufacturing process.
3. A basic understanding of the context in which engineering is practiced, including:
Economics and business practice,
History,
The environment, and
Customer and societal needs.
4. A multidisciplinary systems perspective.
5. Good communication skills:
Written,
Verbal,
Graphic, and
Listening.
6. High ethical standards.
7. An ability to think critically and creatively as well as independently and cooperatively.
8. Flexibility-an ability and the self-confidence to adapt to rapid/major change.
9. Lifelong desire and commitment to learn.
10. A profound understanding of the importance of teamwork.

To reflect the new manufacturing environment, CASA redeveloped the CIM Wheel into the new Manufacturing Enterprise Wheel (Figure 2). According to Tillman (1994) the Manufacturing Enterprise Wheel provides an overview of today's best practices in a manufacturing integrated enterprise. In justifying this new approach, CASA (1993) stated that:

“In the mid-1980s we understood the need to break down the walls between design and manufacturing . We did not articulate other issues so well, such as the importance of simplifying processes before automation and the enterprise with its customers and suppliers. New insight brings us to the new

Manufacturing Enterprise Wheel. This wheel is a graphical index to the knowledge and organizational approach required in today's manufacturing world."

Figure 2 The New Manufacturing Enterprise Wheel.

According to CASA (1993) the new wheel enhances the understanding of six key areas which are critical to success in today's competitive manufacturing environment. They are as follows:

1. The customer becomes the central focus of the organization.
2. The importance of teams and human networking.
3. The interface between knowledge and the system for the purpose of sharing information.
4. A focus on key processes from marketing through design, manufacturing, and customer support.
5. A leaner and more agile organization, and less bureaucratic structure.
6. Recognition and integration of external environmental factors such as customers, competitors, suppliers, and the global manufacturing infrastructure.

Considering this, one can conclude that in order for professionals entering or working in today's manufacturing environment to be successful, they must have the following competencies (Tillman, 1993):

1. Interface successfully with the customer, form teams, and work with a multi-cultural workforce.
2. Gather and process data, and formulate accurate concepts.
3. Determine system and software architecture requirements.
4. Implement and supervise system tests.
5. Manage and control projects.

9 THE COMPARISON OF COMPETENCIES

The new wheel represents an integrated manufacturing environment which requires a workforce with strong technical and people skills. Therefore, the graduates of manufacturing engineering programs must have the knowledge and skills to direct, organize, motivate, and be able to work with today's multi-cultural workforce. SME/CASA (cited in Tillman, 1993) defined a successful enterprise integrator as:

“An individual who can facilitate the implementation of complex business changes using enterprise information technology to enhance products and services. He/She understands the computer and information side of design through manufacturing and can lead companies in the implementation of programs.”

A comparison between the competencies which are presented in the Manufacturing Enterprise Wheel and the competencies taught in engineering programs suggests that there is a need for a greater emphasis and/or improvement in the following curricular areas:

1. People and managerial skills.
2. Written and oral communications skills.
3. Greater emphasis on educating students to work with a multi-cultural workforce.
4. Study of the global market place.
5. More emphasis on resources management.
6. Ethical and environmental responsibilities.
7. Capstone projects emphasizing team work.
8. Greater emphasis on hands-on projects that simulate the real working environment.
9. Cooperative educational experiences.

10 CONCLUSION

Today's engineer is becoming that of an integrator, and more of a coordinator of information, technology, and people. Thus, team work and people skills will play an important role in the work of engineers. Industry needs individuals who are experts in their special area of interest and who have a working knowledge and

understanding of the integrated manufacturing environment (Lahidji,1996). Moreover, the graduates of engineering programs should have the skills, knowledge, and abilities to form and work in teams, collect data, formulate concepts, determine system needs, administer system tests, and determine software architecture. Engineering programs should be based on a broader perspective of engineering, technology, and management and work to integrate content and processes across the curriculum.

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Major Points:

- Explain the new CASA/SME Enterprise model.
- Discuss the competencies learned in Manufacturing Engineering programs.
- Discuss the relationship between competencies represented by the CASA/SME model and the competencies learned in Manufacturing Engineering programs.
- Discussion and suggestion for updating the competencies of Manufacturing Engineering programs.

Summary:

This presentation will help instructors to assess the competencies learned in their Manufacturing Engineering programs by comparing them to competencies needed by industry, and for possible improvement of their programs.

The competitive edge in manufacturing is no longer based upon the utilization of high tech equipment. The advantages associated with possessing high tech equipment has been diminished due to the availability and downward pricing of equipment. For example, in the automobile industry obtaining high tech equipment does not provide a competitive edge over the competitors. Today the emphasis is on continuous improvement, simplifying in manufacturing processes, and optimizing of human resources.