

# A Novel Curriculum for the Associate Degree in Manufacturing Engineering Technology

*by the National Center of Excellence for  
Advanced Manufacturing Education*



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# 1.0 Introduction and Background

The National Center of Excellence for Advanced Manufacturing Education (NCE/AME) was established at Sinclair Community College in January, 1995 to develop curricular materials for manufacturing education programs leading to the associate degree. The National Science Foundation provided primary funding for the center through grant #DUE 9454571 from its Advanced Technological Education (ATE) Program in the Division of Undergraduate Education.

This document presents one result of NCE/AME's efforts: a curriculum design for a novel associate degree program in manufacturing engineering technology. The program is novel in its pedagogy, organization, and content.

## 1.1 Contents of the Report

The main sections of this document are:

- 1.0 Introduction and Background
- 2.0 The Manufacturing Engineering Technology Program
- 3.0 The Curriculum Development Process
- 4.0 A Structured Approach to Competency-Based Curriculum Development
- 5.0 Assessment and Standards of Participant Performance
- 6.0 Relationships to National Skill Standards
- 7.0 Curriculum Outline by Cluster
- 8.0 Curriculum Outline by Typical Path Through the Program
- 9.0 Implementation Status and Future Directions

## 1.2 Background

The National Science Foundation started the ATE program in 1994 to address the education of science and engineering technicians. The program promotes exemplary improvements in advanced technological education at the national and regional level. It supports curriculum development and program improvement for educating technicians for the high-performance workplace. Central to the ATE program is the development of strategies to strengthen college-level technician education and the mathematics, science, and technology education base in secondary schools for those planning to enroll in technician education programs in colleges. The program also includes expanded

opportunities for technicians already employed in industry or enrolled at four-year colleges and universities.

The NCE/AME is one of the first three National Centers of Excellence to be funded through the ATE program. It is housed within the Advanced Integrated Manufacturing Center (AIM Center), a partnership of Sinclair Community College and the University of Dayton in Dayton, Ohio. Numerous partner institutions and individuals have participated in the development of the curriculum and the instructional modules.

Planning for the NCE/AME began in the fall of 1993, soon after the announcement of the intent to start the ATE program. A full proposal was submitted to NSF in the spring of 1994. After a comprehensive site visit in the summer of 1994, notification of the grant award was received in the fall of 1994. Although funding started in January, 1995, project work actually began in the last quarter of 1994.

### 1.3 Overview of the Contents of the Report

One major goal of the NCE/AME is to develop a novel, activity-based, competency-based, contextual, industry-verified, modular curriculum in manufacturing engineering technology that can lead to systemic change in the way technician education is delivered in the United States.

Section 2.0 summarizes the overall nature of the proposed manufacturing engineering technology program. Section 3.0 summarizes the curriculum development process.

The instructional modules within the curriculum incorporate a novel pedagogy that emphasizes learning through a series of authentic learning tasks that give participants experience similar to what they will experience in their careers. The pedagogy emphasizes learning by doing. Section 4.0 presents an overview of the pedagogy and the module architecture.

The authentic learning tasks require the development of authentic assessment methods that gather information about the performance of participants in ways that relate strongly to their ability to perform at a high level in the advanced technological workplace. The results of the assessment activities are related to a set of performance standards to evaluate the level of competence demonstrated by the participant. Section 5.0 presents details of this process.

Many bodies have developed national skill standards initiatives in the United States over the past several years to promote improvement in the performance of employees in high technology workplaces and to provide a more uniform gage of competence. Among these initiatives are the SCANS Competencies (Secretary's Commission on Achieving Necessary Skills), Advanced High Performance Manufacturing Standards (National Coalition for Advanced Manufacturing), Machining Standards, and Computer Aided Drafting and Design Standards. The

National Skill Standards Board has provided some measure of coordination for these standards-development activities. Section 6.0 addresses the relationships between the proposed curriculum and various standards initiatives.

Section 7.0 presents the proposed curriculum. The instructional modules are organized within nine clusters for the convenience of describing the overall content coverage of the curriculum. The curriculum contains 67 instructional modules plus six courses to be taken from regular college offerings.

The modules are generally smaller than traditional courses to promote flexibility in the manner of proceeding through the program and to facilitate assessment of prior competency. Module size cannot be measured in traditional ways. Most existing manufacturing engineering technology programs are organized within traditional quarter or semester systems in which one credit-hour relates to one class-hour meeting per week for the term. The instructional modules in the proposed program are based on the satisfactory completion of a set of activities in which the participant develops specified competencies. Time is not the major metric. Estimates have been made to relate the competencies in each module to the amount of time it would take to cover a similar amount of content in a traditional quarter-based course. Using this method, module size ranges from approximately one to two quarter credits.

Participants start the program with the module called Introduction to World Class Manufacturing, designed to give a taste of much of the complete program. It helps the participant appreciate the big picture of the goals of the program. A major capstone experience completes the program.

Section 8.0 describes how participants proceed through the program. There is no one preferred path. Rather, advisors would guide any given participant, using a form of critical path scheduling based on prerequisites achieved, near-term goals of the participant, and overall priorities for taking certain modules.

While the curriculum outline describes a complete associate degree program in manufacturing engineering technology, only a portion of the instructional modules are to be completed in the grant project. Section 9.0 discusses the status of the module development process and projected efforts for the NCE/AME to complete the balance of the modules.



## 2.0 The Manufacturing Engineering Technology Program

The proposed manufacturing engineering technology associate degree program is designed to prepare the graduate for employment in any production enterprise. The graduates are expected to attain the title of manufacturing engineering technician.

While curriculum details may vary from institution to institution, there are certain core competencies that are expected from all manufacturing engineering technicians in high-performance enterprises.

This section includes a model job description that guided the creation of the curriculum. In general, the manufacturing engineering technician is expected to provide technical support to a variety of other manufacturing professionals and to perform manufacturing operations. Such a job requires a breadth and depth of skill and knowledge beyond that typically attained from a secondary school education.

The program retains the familiar title of manufacturing engineering technology, but it is important to point out the differences between the proposed program and existing, more traditional, manufacturing-related associate degree programs. In response to industry demands, the program places a larger emphasis on production operations, quality, and the tools needed by technicians to participate in product development and process improvement. Technicians need to know how their work with manufacturing systems is integrated with the work of others in the whole enterprise.

Two terms characterize the environment in which manufacturing engineering technicians are expected to work. They participate in the product realization process by which products are developed and implemented: from conceptualization, through production and delivery to the customer, and to eventual retirement and disposal. They are also potential manufacturing engineers, a position that the Society of Manufacturing Engineers calls an operations integrator. This term emphasizes that, while professionals in the manufacturing arena must be technically strong in manufacturing processes and their foundations in mathematics and science, they also must be able to work effectively with professionals throughout the enterprise. They need a carefully selected set of competencies related to the business operations of the enterprise.

While manufacturing engineering technicians will typically need additional experience and education to achieve the position of manufacturing engineer, the associate degree program should provide the foundation and the basic tools to allow them to move in that

direction. This report primarily describes the job for which an associate degree graduate would be qualified immediately upon graduation. Additional description is given for appropriate higher levels of education and the long-term career paths that are possible. This section also describes jobs for which those with only a high school diploma would be qualified.

## 2.1 Model Job Description

The manufacturing engineering technician will work as a key member of the team of people responsible for the manufacture of products and systems within a manufacturing enterprise. The primary tasks of the team will involve production planning and control, production operations management, quality management, manufacturing systems planning and management, and maintenance management. The technician will, in general, assist and support the other team members. Particularly in some small- to medium-sized enterprises, an experienced technician may be given responsibility for some aspects of manufacturing operations.

While working primarily with the manufacturing operations team, the technician will have a continuing need to interface with the other professionals in the enterprise who have primary responsibility for product and system design, purchasing of materials, marketing, sales, and distribution. The job may also require customer contact.

The following subsections provide more detailed descriptions of the activities of the manufacturing engineering technician.

### 2.1.1 Manufacturing Processes and Materials

The manufacturing engineering technician must understand the structure and properties of metallic and non-metallic materials and be able to assist in planning, organizing, implementing, and managing the processing of materials from raw stock through the distribution of a finished product. The technician also must have the ability to apply knowledge of the principles of many manufacturing processes to the proper setup and efficient operation of production systems.

### 2.1.2 Production-Operations Management and Inventory Control

The manufacturing engineering technician will provide assistance and support to the team responsible for planning, analyzing, and controlling the production of products from the acquisition of raw materials through the production and distribution of the products to customers. Included will be the planning and implementation of facilities for production, the effective management of inventory, and the implementation of lean, world-class manufacturing concepts.

### 2.1.3 Quality Management

The manufacturing engineering technician will be able to apply quality principles to the entire collection of activities within an enterprise, no matter where those activities are performed. Particular emphasis will be placed on statistical process control applied to production operations and on the continuous improvement of those operations.

### 2.1.4 Automation, Controls, and Manufacturing Systems

The manufacturing engineering technician will support the team responsible for the planning, design, implementation, use, and maintenance of a variety of systems and controls to monitor production quantities, costs, and quality; providing automated production; and integrating the manufacturing operations with enterprise management systems. The technician also must have the ability to apply and troubleshoot many types of sensors, input/output devices, actuators, and controls.

### 2.1.5 Design for Manufacturing

As a part of a product realization team, the manufacturing engineering technician will participate in the process of analyzing customer needs, volume demands, and market requirements, and conceptualizing and designing a product or service to meet those needs, demands, and requirements. The technician's primary activity will be designing simultaneously the processes, tooling, and fixtures to produce and distribute the product or service in the most productive and least costly manner possible.

### 2.1.6 Enterprise Integration

The manufacturing engineering technician will be a key supporter of the team responsible for the management of a manufacturing enterprise because the manufacturing operations must be integrated with the entire enterprise. Data and information from production operations, product designers, vendors, customers, sales and marketing staffs, and enterprise managers must be acquired and analyzed to evaluate and manage the production operation. Therefore, the manufacturing engineering technician should have knowledge of the enterprise management process so she or he can contribute effectively in support of the efficient management of the enterprise.

### 2.1.7 Lifelong Learning

The associate degree in manufacturing engineering technology is designed to prepare participants to perform the functions of the manufacturing engineering technician. It is expected that such persons will have a strong education in the fundamentals of mathematics, science, communications, and humanities. Such preparation will support on-the-job training and/or continuing education for a baccalaureate degree in engineering technology or related programs. In addition, the technician is expected to maintain a personal program of self-development to stay current in the technology and practices of manufacturing.

### 2.1.8 Interpersonal and Team Building Skills

The manufacturing engineering technician will operate in enterprises in which teams of people from many different backgrounds and with many different levels of education work on projects. The ability to work effectively in a team-based environment is essential. With the continuing development of global sourcing and delivery of products, the manufacturing engineering technician must maintain an awareness of and appreciation for the wide variety of cultures and economic systems present in the world.

## 2.2 Education, Experience, and Employment Expectations

The NCE/AME has developed a curriculum and instructional materials to improve the education of people for entry into the workforce of manufacturing enterprises. The primary focus of the curriculum development is the associate degree program in manufacturing engineering technology. The graduate of this program should be well prepared to enter the workforce as a manufacturing engineering technician.

Another major objective of the Center is the upgrading of mathematics, science, communications, and team-building skills of secondary school participants, particularly in grades 11 and 12, by producing instructional modules and materials (based on constructivist principles) that illustrate the application of key competencies in manufacturing enterprises. Participants graduating from high school with such upgraded skills are expected to be well prepared to enter the manufacturing workforce immediately or to continue their education in associate degree or baccalaureate degree programs in engineering technology or related fields.

The preparation of participants for lifelong learning is a major goal of the NCE/AME. Thus, the participant should be able to enter the manufacturing workforce and return to appropriate educational programs at multiple points: typically after graduation from high school at grade 12, at any point within or at the end of the associate degree

program, and at any point within or at the end of the baccalaureate degree program. The graduate of the baccalaureate degree program should be prepared to enter post-baccalaureate programs in engineering technology or the management of technology.

The following sections discuss the typical jobs for which the high school graduate, the associate degree graduate, and the graduate of the baccalaureate degree in manufacturing engineering technology should be prepared.

### 2.2.1 High School Graduate

A major assumption of the Center's curriculum planning effort is that graduates from high school will have achieved competency up to the proposed twelfth grade standards in science, mathematics, and communications. These standards are being developed and promulgated by the National Council of Teachers of Mathematics and the science educators responsible for the proposed National Science Education Standards coordinated by the National Research Council (refer to Section 3.3).

Implementation of these standards is designed to elevate significantly the competencies of a large number of high school graduates when compared with the typical current level of achievement. The proposed standards are directed toward participants at the middle 75 percent (approximately) of the high school population. While some of the materials being developed may be useful throughout the high school curriculum, they are not intended generally for those who pursue existing college preparatory programs or those who are significantly impaired. High school graduates should possess the basic skills in mathematics, science, communications, and team building to be able to work in positions that require good technical skills and the ability to work productively in teams. They should be prepared to learn quickly the details of specific production operations without remediation in basic skills. Many should have developed an appreciation for the field of manufacturing by involvement in learning activities related to manufacturing processes and operations and by having visited industries during high school.

The high school graduate who chooses to enter the workforce directly should be well prepared for employment in manufacturing enterprises in such positions as:

- **Production Associate** working with equipment and processes that are highly technical. Tasks often require the use of computers and automation systems and the ability to work effectively in teams. Participation in continuous improvement activities is expected.
- **Production Control Assistant** working with manufacturing engineering technicians and professionals in the acquisition and

processing of data and information from the manufacturing processes such as production quantities, inventories, production problems, tooling, and supplies. Tasks often require the use of computers.

- **Warehousing and Distribution Specialist** with skills required to work efficiently with receiving and shipping operations including the use of computer based information management.
- **Quality Control Assistant** with skills to make basic measurements of the quality of products and to perform routine statistical analyses of such data. Good computer skills are essential.
- **Apprentice** developing more skills on the job in such fields as electronic controls maintenance, machining, and equipment repair.

Regardless of the specific positions they hold, high school graduates should be effective participants in the processes of continuous improvement within their companies.

### 2.2.2 Associate Degree Graduate

Compared with the high school graduate, the associate degree graduate would possess higher levels of knowledge and skill in mathematics, science, humanities, communications, computer use, and the technologies of manufacturing. On-the-job experience should prepare the graduate to take more responsibility for the planning and implementation of continuous improvements to operations.

The manufacturing engineering technician would work as a key person supporting the team of people responsible for the manufacture of products and systems within the overall structure of a manufacturing enterprise. Primary tasks would involve assisting and supporting production planning and control, production operations management, quality management, manufacturing systems planning and management, and maintenance management.

The manufacturing engineering technician would also be well prepared to perform first level supervision of production operations.

The manufacturing engineering technician may perform production operations requiring a higher level of skill and technical knowledge than would be expected of a high school graduate.

The graduate could become a maintenance specialist with skills required to maintain production equipment, controls, and plant facilities. The employer would normally provide focused training on the particular equipment in the enterprise.

### 2.2.3 Baccalaureate Degree Graduate

Graduates of baccalaureate degree programs in manufacturing engineering technology are well prepared to perform as professionals in manufacturing enterprises in such positions as Manufacturing Engineer, Quality Assurance Engineer, Production Engineer, Project Engineer, and Facilities Engineer. They may also work in technical sales and technical services representing manufacturers of production equipment.

Having greater depth and breadth of education as compared with the associate degree graduate opens significantly more opportunities for advancement into management of manufacturing engineering, production operations, or technical sales. Graduates with the Bachelor of Science in Engineering Technology (BSET) degree are holding positions such as Superintendent of Manufacturing, Plant Manager, General Manager, Vice President for Manufacturing, and President. The career advancement potential for BSET graduates within manufacturing enterprises generally is limited only by the individual's personal abilities to lead and diligence in keeping up-to-date in technical knowledge and the knowledge of modern manufacturing techniques.

Graduates of BSET programs are well prepared to be entrepreneurs in manufacturing after gaining relevant experience. BSET graduates are often employed by management consulting firms such as Andersen Consulting and Price Waterhouse. Careers in education at the secondary or college level are also very appropriate, provided the graduate achieves the necessary certifications and additional education.

BSET degree graduates are also well prepared to pursue additional education as described next.

### 2.2.4 Master's Degree Graduate

After completing the BSET degree, the graduate may pursue a variety of post-baccalaureate degree programs. Those most appropriate to career advancement in a manufacturing enterprise are:

- Master of Business Administration
- Master of Technology Management
- Master of Science in Management Science
- Master of Science in Engineering Technology
- Master of Science in Industrial Administration
- Master of Science in Computer Science

Earning such a master's degree typically provides the graduate with greater opportunities for advancement by developing additional capabilities in the management of the enterprise or in the technology of manufacturing. These capabilities often accelerate the promotion to upper levels of management and technical responsibility.

## 3.0 Curriculum Development Process

The actual curriculum development process began during fall of 1994, prior to the start of funding from the NSF. In fact, conceptual planning took place during the proposal development process in 1993–94, as industry and academic professionals met to determine the needs of industry and to translate those needs into the goals of the project.

The proposal process determined that the primary focus of the curriculum development process would be to develop an industry-driven, competency-based, modularly-structured, integrated curriculum for an associate degree in manufacturing engineering technology. The meanings of these terms, as used in the project, are:

- **Industry-driven** means that the set of competencies developed by participants would meet the needs of manufacturing industries for manufacturing technicians with appropriate skills and knowledge.
- **Competency-based** means that the curriculum would guide the participant to develop necessary skills and knowledge that would enable her or him to perform at a high level as a manufacturing engineering technician. This term also implies that a person could demonstrate competency in a variety of ways outside the normal “credit for time spent” mode of traditional curricula. Emphasis is on what the graduate of the program can *do*.
- **Modularly-structured** means that the program would be delivered in a very flexible manner in instructional units smaller than traditional three quarter-hour credit or three semester-hour credit courses.
- The term **integrated curriculum** means that the modules of instruction would be interconnected and that the relevance of one module to another would be reinforced throughout the curriculum. Participants completing the program would see how each competency is related to the career of a manufacturing engineering technician.

### 3.1 Basic Philosophy

To guide the curriculum development process, the project team decided to adopt recommendations of the Society of Manufacturing Engineers (SME), the professional society responsible for the field of manufacturing engineering, of which manufacturing engineering technology is a part. SME has engaged in planning and coordinating the continuous improvement of manufacturing education for many years.

Two recent landmark documents called Curricula 2000 (1990) and Curricula 2002 (1995) describe recommended content and organization of manufacturing engineering technology programs at the associate, bachelor, and master's level (refer to Section 3.3). While a great deal of specific information is contained in these documents, a quote from the executive summary of Curricula 2002 serves to characterize the basis for the project's curriculum development.

Manufacturing education should be comprised of five sets of principles. These embrace product functionality, engineering materials, manufacturing processes, manufacturing infrastructure, and the business enterprise. Throughout the educational process, at all levels and in all styles, manufacturing must be treated as a system. Everything that happened in the product realization process influences and is influenced by all of the other steps. Thus, manufacturing must be addressed in a systems context, beginning with the first course. (P. ix)

Traditional manufacturing engineering technology programs have included very strong, comprehensive sequences of courses in manufacturing processes and materials for many years, with particular emphasis on metalworking. In such a curriculum, there is little room for the broad array of principles described in the quotation above. Therefore, curriculum development for the proposed program sought to retain essential concepts of manufacturing processes and materials while adding significant principles from product design, manufacturing infrastructure, and the business enterprise.

The technological components of the curriculum are based on sound foundations in mathematics and science. Of equal importance are the principles of communication, teamwork, and the humanities, so the graduate will have the necessary tools to interact with the wide array of associates, vendors, and customers to whom the manufacturing professional must relate.

Lifelong learning is another important principle in the curriculum development process. This principle made it important to design the program to be accreditable by the Technology Accreditation Commission of the Accreditation Board for Engineering and Technology (TAC/ABET). This would facilitate the transfer of graduates of the associate degree program to baccalaureate degree programs in manufacturing engineering technology throughout the country. It would also be an important form of external verification that the graduate possesses the essential competencies to perform as an engineering technician in a high-performance industrial enterprise.

### 3.2 Target Job Description

The target job description for the graduate centers on the capability to work effectively in any company that produces a product. The

comprehensive job description is included in Section 2.1 of this report. Included are descriptions of a variety of specific job titles that would be appropriate for the associate degree graduate and comparisons with jobs in manufacturing industries that would normally be held by high school graduates and those with baccalaureate degrees or higher.

The following is the summary description of the manufacturing engineering technician as used in this project.

The manufacturing engineering technician works as a key member of the team of people responsible for the manufacture of products and systems within the overall structure of a manufacturing enterprise. The primary tasks of the team involve production planning and control, production operations management, quality management, manufacturing systems planning and management, and maintenance management. The technician, in general, assists and supports the professional members of the team. Particularly in some small- to medium-sized enterprises, an experienced technician may be given responsibility for some aspects of manufacturing operations. While working primarily with the manufacturing operations team, there is a continuing need for the technician to interface with other professionals in the enterprise who have primary responsibility for product and system design, purchasing of materials, marketing and sales, and distribution. Customer contact is also to be expected. (NCE/AME, "Curriculum Development Process," 1997, p. 3)

### 3.3 Resources Used in Developing the Curriculum Competencies

After specifying the target job description for the graduate, a large group of faculty and staff from Sinclair Community College and the University of Dayton developed the initial list of competencies that the graduate should demonstrate.

The major resources used included:

- *Society of Manufacturing Engineers (SME) documents Curricula 2000 and Curricula 2002* that outline the recommended content of any type of college-level program in fields related to manufacturing engineering, including the associate degree in manufacturing engineering technology
- recommended twelfth grade standards of the National Science Education Standards
- recommended twelfth grade standards of the National Council of Teachers of Mathematics
- standards and recommendations of the American Association of Teachers of Mathematics in Two-Year Colleges

- SCANS competencies developed by the U.S. Department of Labor Secretary's Commission on Achieving Necessary Skills
- several voluntary industry skill standards developed under the guidance of the National Skill Standards Board, particularly those called *Advanced High Performance Manufacturing*, *Computer Aided Drafting and Design (CADD)*, and *Machining*
- other industry skill standards such as:
  - Washington State Manufacturing Technology Standards as developed and promulgated by the Manufacturing Technology Advisory Group, Seattle, Washington, 1995
  - Machining and Metalworking Skill Standards as promulgated by the National Institute for Metalworking Skills (NIMS) and the National Tooling and Machining Association (NTMA)
  - *Setting the Standard— A Handbook on Skill Standards for the High Tech Industry*, Workforce Skills Project, American Electronics Association, Santa Clara, California, 1994
  - *National Photonics Skills Standard for Technicians*, Center for Occupational Research and Development, Waco, Texas, 1995
- *Sinclair Community College Bulletin*, 1995–96, Sinclair Community College, Dayton, Ohio
- *University of Dayton Bulletin*, 1995–96, University of Dayton, Dayton, Ohio
- selected competencies developed by the Miami Valley Tech Prep Consortium

Emphasis was placed on solid foundations in mathematics, science, communications, teamwork, manufacturing processes, materials science, automation, manufacturing systems, controls, quality management, production and inventory control, the product realization process, and enterprise integration.

The proposed list of competencies includes a much broader set of topics than has been typical in manufacturing engineering technology programs that focus on metalworking technologies.

Enterprise integration includes the fundamentals of business management at a level appropriate for a manufacturing engineering technician for understanding the place of her or his work in the enterprise.

The list also included competencies appropriate to high school preparation in grades 11 and 12 in mathematics, science, communication, and teamwork skills.

A secondary consideration was articulation with a BS degree program in engineering technology.

### 3.4 The Competency List

Competencies can be developed at several levels of specificity. One classification scheme describes three levels: primary, secondary, and tertiary. For the purpose of this discussion, these levels are described by example as follows:

- Primary level competencies are at a high, general level. Example: Demonstrate the ability to analyze and apply electrical and electronic principles.
- Secondary level competencies are statements of what participants should be able to do in a fairly specific topic area. Example: Analyze basic electrical series and parallel circuits.
- Tertiary level competencies are quite specific and might be used to plan a specialized learning activity. Example: Determine the flow of current through a resistor in a series AC electrical circuit when the applied voltage and resistance are known.

For basic curriculum planning, project staff decided that the competencies would be stated at the secondary level. During the development of specific instructional modules, authors who are content experts were asked to develop the tertiary level competency statements around which authentic learning tasks were designed.

Inputs from the many faculty members that contributed competency statements were collected on a form called the NSF/ATE Competency Worksheet. One of the principal investigators, with assistance from several of the participants, organized the competencies into subject matter categories. Duplications were eliminated.

Staff developed an extensive database document from the refined competency statements to allow for sorting by category. A hierarchy with major headings described groups of competencies. The result was a list of approximately 800 individual competency statements that came to be known as “The 800 List.”

Because of the large number of modules anticipated for the curriculum, staff decided to arrange the competencies into nine clusters, where a cluster is a set of instructional modules within a given field.

The names of the clusters changed over the period of curriculum development, but the general nature of the clusters varied little. The clusters are:

- Principles of Mathematics
- Principles of Science

- Humanities, Communications, and Teamwork
- Design for Manufacturing
- Production and Inventory Control
- Quality Management
- Manufacturing Processes and Materials
- Manufacturing Systems and Automation
- Enterprise Integration

### 3.5 External Validation

The project team sought external validation to determine whether or not the list of competencies was appropriate for an associate degree program in manufacturing engineering technology. The team decided that “The 800 List” was too cumbersome and detailed for acquiring the necessary cooperation of external evaluators. Therefore, the major headings on groups of competencies were extracted and organized into an evaluation document. These major headings are essentially the primary competency statements.

The resulting list had 175 items and came to be known as “The 175 List.” The curriculum development team used this list for obtaining external feedback from industrial and academic professionals. The team asked evaluators to rate each item in the list as 1) vital, 2) important, 3) desirable but not critical, and 4) not important. A separate report on this evaluation of curriculum competencies is available.

The results of the external evaluation provided useful guidance to the curriculum development team’s assigning priorities among competencies when it was impractical to include every one in the curriculum.

### 3.6 Development of the Curriculum Outline

Members of a curriculum coordination committee reviewed “The 800 List” of competencies to determine how the competencies should be arranged into the nine clusters for the purpose of developing instructional modules. Committee members represented a diverse array of academic disciplines that covered the cluster areas for the most part.

Committee members allocated competencies to the clusters using the code P (Primary) to designate the cluster in which the competency should be introduced and where participants should develop the basic level of competency.

Committee members used the code I (Integration) to identify other clusters in which certain competencies should be integrated with other

competencies and where participants could develop higher levels of competency (that is, higher on Bloom's Taxonomy).

The curriculum coordination committee then developed a list of modules within each cluster and allocated competencies to the modules.

### 3.7 Module Size

To achieve flexibility in the delivery of the curriculum, the team decided that the basic size of modules of instruction would be somewhat smaller than the traditional course in a college curriculum, typically three or four quarter-hour credits or three semester-hour credits.

Traditional quarter- or semester-hour credits are assigned based on the amount of time participants spend in class during a given course. One hour per week for the entire quarter or semester is the nominal standard.

Because of the pedagogical decision to develop a competency-based program using activity-based learning rather than lecture, a direct correlation between module size and quarter-hour credits ("seat time") was not established. Instead, the concept of equivalent hours of instruction (EHI) was developed to define the size of a module.

Nominal module size was set at the number of competencies that could be developed by a participant in a time corresponding to approximately one quarter-hour credit if the material in the module were to be taught in a traditional lecture mode. This would be equivalent to 10 hours of instruction. Module sizes in the curriculum range from 10 to 30 EHI.

The curriculum committee members estimated the size of the modules (in EHI) and judged what prerequisite competencies would be required by participants. Cluster captains and module writers adjusted these preliminary decisions as the module development process unfolded.

The committee combined clusters and modules to form a curriculum outline. Some of the mathematics, science, computer skills, and communications modules were considered to be appropriate for coverage at the secondary school level for participants who complete high school with the levels of competency called for in the proposed twelfth grade standards. Most of the remaining modules were allocated to the associate degree program. Some of the modules that were originally proposed were relegated to baccalaureate degree programs in order to achieve an associate degree program of reasonable size.

### 3.8 Module Development Process

The project team recruited cluster captains who would take charge of finalizing the modules in a particular cluster, recruiting authors for the modules, and coordinating the module development with the project staff and with other cluster captains.

Each module author reviewed the statements of competencies provided in the curriculum outline and made suggestions for modifications. Prerequisites were also examined and refined. Often this required discussions with the cluster captain, with other cluster captains, with project staff, or with other module writers.

Each module author was expected to identify an industry champion who could document how the competencies included in the module are used in that particular company or organization. A company description was included in the module so participants could relate to real situations as they develop the competencies. In many cases, some of the authentic learning tasks in the module were designed around actual tasks performed by people in the profiled company.

Each module author was expected to develop the module in accordance with author guidelines and guiding principles provided by the project staff. Section 4.0 describes these guidelines and the pedagogy on which they are based.

### 3.9 Integrating Manufacturing Experience

Concurrent with the development of early modules in the second year of the project, the project staff introduced the concept of the integrating manufacturing experience to enable participants to see an integrated set of modules throughout the curriculum. Each technical module and others from the mathematics, science, and humanities/communications/team building clusters were expected to use some aspect of the integrating manufacturing experience as the transfer activity in the module.

For the purpose of initial module development, the project staff defined a sample integrating manufacturing experience. The project staff created a hypothetical company called Robotic Grippers, Inc. that designs and produces a line of pneumatically operated robotic grippers. Descriptions of the company, its facilities, its markets, and its product lines were developed and provided to the module authors. Prototypes and drawings of the grippers and their component parts were provided.

The integrating manufacturing experience is one of the keystones of the curriculum.

### 3.10 Accreditation Issues

Because of the nontraditional structure and content of the curriculum, it is likely that the program would not meet the current (1999) general criteria for accreditation by TAC/ABET as an associate degree program. However, the curriculum was designed to meet the intent of the criteria, and steps have been taken to anticipate the issues that would arise when an application for accreditation is made for a program adopting the proposed curriculum. These issues were shared with the National

Advisory Committee for the project, with the Non-Traditional Programs Committee of TAC/ABET, with the Criteria Committee of TAC/ABET, and with the Executive Director of ABET, who is a member of the National Visiting Committee for the AIM Center. While details remain to be completed, strong support for the modular structure and the pedagogical innovations has been received.

### 3.11 Articulation Issues

Articulation from the associate degree to BSET degree programs is another major issue. The modular structure will result in participant records which appear different from the transcripts for participants who have completed associate degrees in traditional quarter or semester systems. Approaches to resolving these issues are being developed. One approach is to prepare an *Index to the Body of Knowledge* that will relate the competencies developed by participants to more traditional courses in mathematics, science, communications, the humanities, and technology.



## 4.0 A Structured Approach to Competency Based Curriculum Development

The mission of the National Center of Excellence for Advanced Manufacturing Education (NCE/AME) is to provide national leadership in developing manufacturing engineering technicians with strong fundamental and technical skills. An interdisciplinary team of educators and practitioners is working to develop a cohesive curriculum that integrates the core skills of mathematics, science, communications, and analytical problem solving with the concepts of world-class manufacturing.

This interdisciplinary team has identified a structured approach for developing the competency-based curriculum. This ensures that our diverse group of practitioners and educators have a common ground for the long-term developmental effort, and it enables subject-matter experts to develop curriculum modules that are educationally sound, even if they are not professional curriculum authors or learning-theory specialists.

The strategy described here accomplishes a delicate but critical balance. It produces a technological curriculum that is consistent and replicable from one setting to another with individual modules that remain flexible, dynamic, and robust. A simple pattern delineates the basic learning strategy and serves as the blueprint for individual modular construction. This approach emphasizes a hands-on, competency-based process, where skill-building activities are coupled with fundamental theoretical knowledge throughout the educational experience. The end result is a manageable system for holistic technological learning.

### 4.1 Providing Learning Contexts

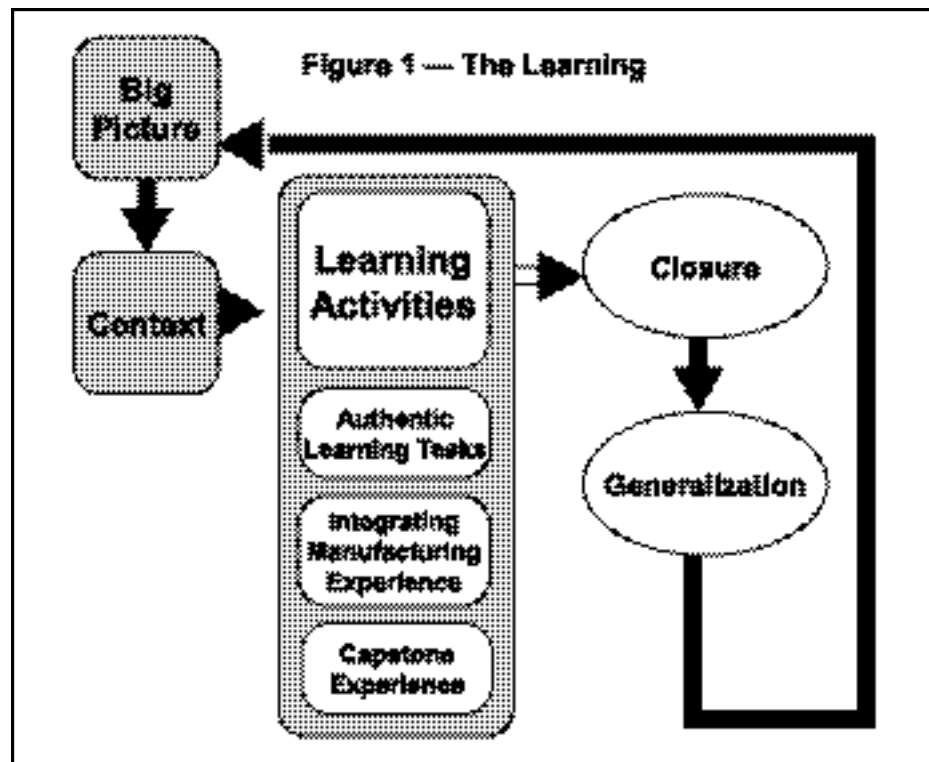
Performance-centered learning cannot occur in a vacuum. Therefore, the team delineated a central learning pattern that anchors each learning activity to real world applications (refer to Figure 1).

To accomplish this, each instructional module is launched with a discussion of the big picture or general framework. This ensures participants can envision the full breadth of situations where the upcoming knowledge and skill might be applied in the world. To make each task manageable and meaningful, the model defines a specific context or setting, so that a specific set of competency-building tasks can be tackled.

For the purposes of this model, we have defined these two elements as follows:

- **The Big Picture:** The big picture is the framework for learning. Before specific theories and skills are tackled, instructors construct a framework by defining the value these theories and skills have and the ways in which they might be used on a day-to-day basis.
- **Context:** Context is the foundation for application. In order to mesh theory with practice, specific settings are described or replicated in the classroom, so that learning tasks can be pursued with an understanding of why and how specific tasks are performed in the real world.

By delivering modules within the framework of the big picture and context, the model ensures that participants, as they move from the general to the specific, are able to construct a unified body of knowledge and skills.



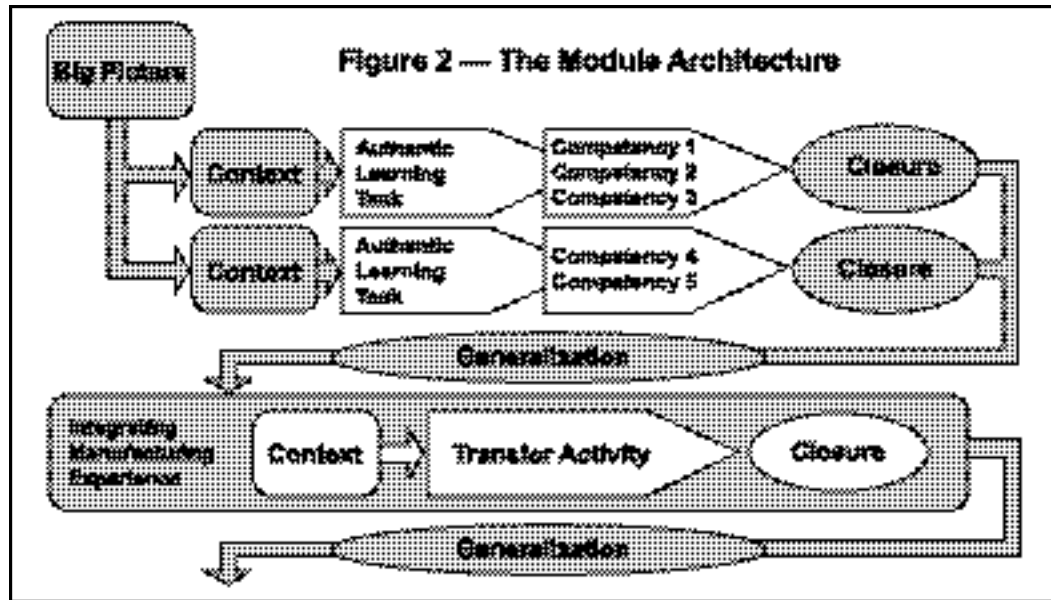
## 4.2 Building Competencies

Instructional modules constitute the basic delivery system. They are interrelated and flexible, and they are designed to help participants master a relatively small set of select competencies (refer to Figure 2).

Each learning activity encourages participants to translate that experience to other learning activities and to the world. Hence, modules may be presented in a variety of sequences, so participants encounter new theories and practice new applications at the learning stage most appropriate for them. In combination, a cluster of modules will build a broad range of knowledge and competencies specific to each participant's program of study. Briefly, the basic elements can be described as follows:

- **Authentic Learning Tasks:** Authentic Learning Tasks (ALTs) are a series of discrete learning events that build experience and competencies related to the module's goals. ALTs often replicate a real world application, but they are more limited in scope. Their primary focus is to build specific skills or competencies.
- **Competencies:** A competency is a specific ability which has been adequately developed so performance is consistent in a variety of situations and over time. Typically, each ALT integrates two or more competencies.  
A single module incorporates several authentic learning tasks, designed to build a range of skills. In each ALT and transfer activity, authentic assessment processes verify the competencies.
- **Closure:** To help participants apply competencies to other situations, each ALT concludes with a closure segment. Closure may be a discussion lead by the instructor, a recap of the original big picture and context, or it may be an activity participants perform as part of the authentic learning task. Once closure occurs, participants begin to project new skills and knowledge to other lessons and real world situations.
- **Generalization:** Generalization unites a series of ALTs into a synthesized perspective. While ALTs rely on the incremental application of distinct skills and theories, structured generalization helps participants build a bridge between the known, specific applications they have just completed and the anticipated but unknown applications they will eventually encounter.

A module contains a cluster of ALTs that focus on skill building and basic synthesis within a specific context. When an entire cluster of learning tasks is completed, facilitators guide participants through generalization to help develop connections among the entire range of recent learning activities and link these activities back to the real world.



### 4.3 Solidifying Performance Capabilities

When participants have completed an appropriate cluster of ALTs and developed a sound mix of skills and knowledge sets, they are ready to progress to a new stage of learning. This stage focuses on assimilation, characterized by a series of structured activities called transfer activities, the integrating manufacturing experience, and the capstone experience (refer to Figure 1). Briefly, these elements can be described as follows:

- **Transfer Activities:** Transfer activities present a more complex learning activity designed to help participants develop relationships among learned competencies and to encourage participants to apply these in challenging new ways. Transfer activities typically occur at the end of a module or at the end of a series of related modules, and their purpose is to unite skill and theory in an occupationally verified manner. Transfer activities serve as a unifying thread. They weave throughout the entire program of study, and in combination, they produce a cohesive learning experience.
- **Integrated Manufacturing Experience:** The integrated manufacturing experience is not a separate event; it is the end product of a full series of transfer activities. Since the goal is to build a coherent picture of a specific discipline in action, a logical integrated manufacturing experience might include following a

product from concept through execution and delivery. The focus of the integrated experience can be altered to reflect regional industries, so the participants can build specific skills and abilities related to their likely work environment.

- **Capstone Experience:** Many technical programs conclude with a practicum, but this model presents a new perspective. Traditional practicums are controlled projects designed to allow participants to practice a range of specific skills and knowledge sets within an industry setting. Because the curriculum architecture incorporates this function into the academic arena, the concluding practicum becomes a stronger, more flexible, and more realistic experience. As a result, capstone experiences are focused, specific, and designed to meet an actual, rather than artificial, industry need. The capstone experience could occur in the participant's existing employment environment or in a local model manufacturing facility (a "teaching" factory). Typically, capstone experiences involve a team comprised of other participants, experienced co-workers, or some mix of the two.

Participants develop theory and demonstrate competencies in protected settings through the cumulative learning activities and the integrated manufacturing experience. Once this foundation is firmly in place, they then apply these competencies in realistic settings, through the capstone experience.

#### 4.4 Fifteen Learning Statements

The module architecture and the pedagogy incorporated in the modules are based on the following 15 learning statements. The statements present the philosophy of learning adopted by the NCE/AME project team.

1. Learning is a lifelong process.
2. Learners construct their own knowledge and understanding of the world in which they live.
3. Learners search for tools to help understand their experiences.
4. Learners come to classrooms with different backgrounds, knowledge, skills, values, and experiences.
5. Learners have preferred modes of learning. Activities need to be structured so learners can utilize their preferred mode of learning, as well as have the opportunities to develop skills in using other modes of learning.
6. Learners must be active participants in the learning process.

7. Learners need opportunities for real, hands-on and/or concrete experiences.
8. Learners should be challenged to build on past experiences to create new schemes or structures.
9. Learners should be allowed to explore, experiment, and discover.
10. If learners see the value of the learning, they will become active seekers of knowledge and will assume responsibility for learning.
11. Learners grasp the meaning of concepts more easily when they go from “whole to part” rather than “part to whole.”
12. Learners need opportunities to develop metacognitive and interpersonal skills and need time to reflect on their learning.
13. Learning to learn is an important skill that needs to be emphasized in all content areas.
14. All areas of development, which include the areas of motor-, thinking-, language-, and social-emotional-skills, are used when a learner is in a “learning situation.”
15. A higher degree of learning occurs when the experiences are integrated, which involves many different subjects and skills being used at the same time. Learning is not integrated when each subject is treated separately and learners are expected to integrate the subject matter and skill at some future date.

#### 4.5 Guiding Principles for Curriculum Development

Prior to beginning the actual development of instructional modules, the project team defined a set of seven guiding principles that authors are expected to adhere to as they develop each module. To the extent possible, each of the guiding principles should be evident within each module. In this way, participants gain valuable continuity of experience and reinforcement of these important principles. They become more internalized as the participant progresses through the program.

##### 1. Scientific Methods

*Program Goal:* Use scientific processes to formulate questions and plan investigations; collect and interpret data; formulate and revise explanations and models using logic and evidence; analyze alternative explanations and models proposed by others; communicate and defend scientific conclusions.

- Participate in planning a significant aspect of their work during the module.

- Collect and interpret data either through hands-on activities, or through observations of videos or other records of real or realistic events, or through selection of real data from appropriate sources.
- Make predictions, formulate explanations, or propose general rules which extend beyond the immediate situation.
- Analyze at least one alternative explanation, interpretation, or solution.
- Express conclusions in a written or oral form that allows others an opportunity to respond.

## 2. Written Communication

*Program Goal:* Demonstrate the ability to write with a purpose in different formats for a variety of audiences and to organize, synthesize, and communicate the significance of their technical or nontechnical information.

- Collaborate with peers and/or facilitators during one or more stages of the writing process, gathering information, organizing and developing information, formulating purpose, analyzing audience, drafting, revising, proofreading.
- Describe in writing a basic module concept or issue.
- Apply, analyze, synthesize, or evaluate key module concepts or issues.
- Use writing formats such as direct request letters, routine and non-routine reports, and empirical research reports when they are applicable to learning or when they would be regularly required in the workplace (required in technical modules).
- Use writing formats such as explaining causes or effects, arguing a position, or identifying and solving a problem; as well as summarizing, synthesizing, or critiquing researched information in order to learn a discipline (required in nontechnical modules).

## 3. Oral Communication

*Program Goal:* Effectively communicate with, listen to, and respond to others interpersonally, in teams or through presentations.

- Compose a message and provide ideas and information suitable to the topic, purpose, and audience.
- Transmit a message by using oral delivery skills suitable to the topic, purpose, and audience.

- Listen with critical comprehension.
- Interact with others to solicit and disclose feelings, opinions, and viewpoints openly.

#### 4. Teamwork

*Program Goal:* Demonstrate a cooperative effort in a group to evaluate, solve problems, and develop and implement plans and procedures.

- Collaborate with others in establishing or clarifying the direction, purpose, and character of a team.
- Collaborate actively within a team on course topics or projects to achieve the team's purpose and promote learning.
- Interact effectively with the facilitator, mentor, other groups, or other constituencies.

#### 5. Diversity and Fair-Mindedness

*Program Goal:* Demonstrate a willingness to fair-mindedly assess the moral viewpoints or reasoning of others, regardless of one's own bias, as well as a willingness to imagine oneself in the place of others in order to genuinely understand them.

*Development Questions:*

- Are any people portrayed within the module whose race, gender, or ethnic or national origin is identifiable and who are portrayed as making significant mistakes, showing poor judgement, harming other people, or otherwise engaging in inappropriate behavior?
- Is the language within the module consistently gender-fair, including the use of gender-neutral terms whenever possible?
- Are participants expected to discuss, write about, or form judgements about the views or actions of any person who is identified within the module by racial, ethnic, gender, or similar characteristics?

#### 6. Global and Societal Awareness

*Program Goal:* Demonstrate an awareness of the relationship between each module and the local, national, or global community.

*Development Questions:*

- Does the module identify any local communities by name, socioeconomic category, urban or rural location, or in similar ways?

- Does the module include any references to nations or regions outside the United States?

## 7. Career Applications

*Program Goal:* Demonstrate how major concepts and processes of each module apply to careers in science and technology.

- Use major concepts or processes from the module in an actual or realistically simulated workplace environment.
- Work with major pieces of specialized equipment that participants know might be encountered on the job.
- Use major concepts or processes from the module in a classroom activity that clearly and explicitly emulates workplace activities.
- Observe and analyze actual workplace activities in which the module's concepts or processes are applied.
- Interact with a person whose work includes use of the module's concepts or processes.

## 4.6 The Bottom Line

The described development strategy has several distinct advantages. It provides a consistent, replicable system for developing quality modules. It enables subject matter experts to develop sound curriculum modules, even if they are not professional curriculum authors or learning-theory specialists. It also enables both leading-edge educators and practitioners to design new modules which mesh with the fundamental curriculum design.

Theory and skill development are united throughout the program. The linkages between education and real world application are systematically incorporated into the beginning of each module, throughout the execution of learning tasks, and prior to the close of the module. As participants complete each cycle of forecast, execution, and review, they become capable of extrapolating each learning experience to other learning experiences and to industry-specific settings.

This structured, incremental system builds skills, knowledge sets, and abilities within an informed context. The active involvement of industry in module development and advanced learning activities (transfer activities, integrating manufacturing experience, and capstone experience) enriches the participant's educational preparation and ensures that technical graduates have the breadth and depth of competencies their future employers want, need, and value.

**Note:** A complete description of these concepts is presented in white paper, “Architectural Pattern in Curriculum Development.” Call NCE/AME at 937-512-5357 to request a copy.

# 5.0 Assessment and Standards of Participant Performance

The use of an authentic, activity-based approach in the instructional modules inherently involves little or no traditional lecture. Instead, the instructor (called a *facilitator* in this project) guides the students (called *participants* in this project) through a series of authentic learning tasks (ALTs). As the participants complete the tasks, they are expected to develop specified competencies that are similar to those they will use in their careers as manufacturing engineering technicians. The activities call for the creation of specified deliverables from which the facilitator can assess the degree to which the participant has developed the desired competencies. Often actual performance of the task demonstrates competence.

The ALTs almost always require cooperative work by teams of participants. This presents different issues in assessment and evaluation as compared with traditional lecture-based courses in which individual testing is the norm.

Because this approach is so different from the traditional lecture, it is logical to expect that facilitators should use different assessment and evaluation techniques. Traditional testing is often not appropriate or, at least, not sufficient, to provide the facilitators with proper information on which to judge whether the participant has achieved the desired competency.

## 5.1 Principles of Assessment and Evaluation

The following are the definitions of *assessment* and *evaluation* used in this project.

*Assessment* is the process of gathering information about what learners know and can do. The following are guiding principles of assessment used in this project.

1. Assessment is an ongoing part of everyday classroom activities. Teachers, learners, peers, and industry contacts participate in the assessment process.
2. Assessment methods need to take into account individual differences and learning styles. Methods should promote problem solving and creativity and the learner's own assessment of his or her progress.
3. Assessment methods are planned and structured to reflect real life interdisciplinary challenges and often require collaboration with other learners.

4. Multiple assessment methods, over an extended time period, provide learners with the opportunity to reflect, revise, and receive feedback from several sources to enhance understanding, growth, and development.
5. Portfolio assessment provides a means of assessment that is continual, multidimensional, collaborative, knowledge-based, and authentic.
6. Assessment methods and instruments should be linked with the deliverables called for in the module and with the competencies that the participants are expected to develop.

*Evaluation* is the process of interpreting and making judgments about information gathered during the assessment process. Both formative and summative assessment are necessary. The following principles guided the development of the evaluation dimension in this project.

1. Formative evaluations occur during the performance of an ALT. They ensure that the participants take appropriate approaches to the task to develop the specified competency.
2. Formative evaluations are essential to both the learner's mastery of the material and the ability to take responsibility for his or her own learning.
3. Summative evaluation techniques are employed at the end of each activity and at the end of the entire module to verify that the participant has developed the specified competency.
4. The multiple assessment methods call for a variety of evaluation techniques, matched to the nature of the assessments.
5. Rubrics are used to define standards of participant performance.
6. Testing may be appropriate for demonstrating knowledge of facts and for some kinds of problem-solving competencies.
7. An evaluation method called ranking tasks is effective for analytical work requiring the participant to demonstrate an understanding of underlying scientific or technical principles of an activity.

## 5.2 Authentic Assessment Of Participant Competency

The guidelines for assessment and evaluation lead to the use of assessment methods that are more performance-based than traditional testing. The forms of assessment that are recommended for use in modules are:

- scoring rubrics
- checklists with rating scales

- ranking tasks, particularly for analytical subject matter
- presentation evaluations using rating scales
- portfolios
- project reports describing the results of an activity with emphasis on process
- self-assessment tools
- peer assessment tools emphasizing teamwork

Examples of these approaches have been incorporated into modules currently in production. One reference used to identify possible assessment methods is the book, *Classroom Assessment Techniques—A Handbook for College Teachers*, 2nd ed., by Thomas A. Angelo and K. Patricia Cross.

Authors of modules are assisted in their selection of assessment methods by project staff members at several stages of the module development process: as the activities are being defined, later as the activities are formalized, and during the final phases of module production. Because the module development process calls for much of the actual writing to be done by staff members, there is a high level of consistency in the quality and completeness of assessment among the modules.

Module authors specify the factors to be assessed and the acceptable level of competence. They are employed to be the subject matter experts and are expected to be familiar with the needs of industry for the application of the competencies within their modules. The cluster captain and the industry champion also often participate in this process.

### 5.3 Assessment Levels

Project goals demand that the learning experiences be *competency-based* and that the assessment be *authentic*. This is accomplished in the instructional modules by assigning levels of participant (student) performance on a three-level scale. The following terms designate the levels:

- Needs Improvement
- Competent
- Highly Competent

Participants are expected to demonstrate the ability to perform at least at the Competent level on each rating factor for each authentic learning task and transfer activity in each instructional module. The Highly

Competent level recognizes performance that is significantly better than Competent.

*Webster's New World Dictionary*, Third College Edition, provides a range of definitions for the word "competent." The first is "well qualified," "capable," "fit." This is the definition used in the competency-based program. The curriculum's goal is that every graduate be capable of good performance in industrial jobs where manufacturing engineering technicians typically work.

It is important to ensure a high degree of consistency in establishing the Competent level to enable facilitators to evaluate fairly the development of competencies. Efforts are made to frame each statement of competency in assessment instruments in positive terms, stating what the participant is able to do and not what they failed to do relative to some higher level of expectation.

The Highly Competent level recognizes the accomplishment of a person who does produce better than competent work. Participants do perform at different levels, because of basic intelligence or extra effort or both. Highly Competent sets a goal for performance at a significantly higher level than Competent, but one that some participants should be able to achieve.

This system of assessment and evaluation is a clear departure from the traditional A, B, C, D, F grading system. The novel activity-based architecture of the NCE/AME instructional modules calls for a different approach that should lead to a very different mindset for participants and facilitators. A participant's goal should be to *demonstrate competence* rather than to *earn a grade*.

The Competent level is well above the common perception of a traditional C grade. The C grade in traditional scoring systems often means that a given participant's average performance (often expressed as a numerical score) is at a "value" above some cutoff. Individual instructors set the standard for the cutoff. Even where numerical averages are used, different scales are adopted by different instructors. Some use 90–100 as an A; 80–89 as a B; 70–79 as a C; 60–69 as a D; and below 60 as F or failing. Others may use tighter or looser standards. Within the total number of "scores" earned by a participant, there are likely to have been some failures on tests or assignments or, at least, with regard to some concepts or skills expected in the class. These would certainly be rated at Needs Improvement in this framework and would not be acceptable.

This curriculum calls for each participant to demonstrate the Competent level on each aspect of assessment and evaluation. For this reason, the Competent level is well above the common perception of a C. Users must not think of it in the sense that Competent implies mediocre work.

## 5.4 Standards For Participant Performance

The following list describes the standards of evaluation expected for each activity and each module. The list has been used to define the assessment and evaluation methods used in modules produced by the NCE/AME. Module authors and instructional designers have implemented these standards.

1. Summative assessment of participant performance should be done at the end of each authentic learning task and at the end of the transfer activity in each module. A variety of authentic assessment techniques should be used in each module. *Authentic assessment* means that the participant is expected to demonstrate competency while performing some task that is substantial and meaningful in a real life context that is highly relevant to a field in which the competency is typically applied.
2. Participant performance levels are rated on a three-level scale with the following designations:
  - Needs Improvement
  - Competent
  - Highly Competent
3. Competent is defined as “well qualified,” “capable,” and “fit” for employment in a field in which the competency is typically applied.
4. Highly Competent is defined as “adept,” “highly skilled,” and “highly proficient.” A participant rated at this level should be able to perform at a very high level in an employment field in which the competency is typically applied. The Highly Competent level is used to designate performance that is significantly better than Competent.
5. A rating at the Needs Improvement level indicates that the participant has not completed a required task at the Competent level.
6. Participants are expected to perform at least at the Competent level on each rating factor for each authentic learning task and transfer activity in each instructional module.
7. A participant who is rated at the Needs Improvement level on any rating factor must overcome the observed deficiency and demonstrate performance at the Competent level before being certified as having developed the competencies for that particular learning task.

8. Standards for participant performance at the Competent and Highly Competent levels are to be defined for each assessment factor in each authentic learning task and each transfer activity in each module. The standards should be defined by the module development team, including at least one industry professional who has knowledge of the expected level of performance of engineering technicians in a high-performing industry in which the competency is typically applied.
9. The instructional designers are expected to produce the written statements of the standards in forms that are consistent from module to module throughout the curriculum. Statements of competency are to be positive statements that describe what the participant does to demonstrate competency. Highly Competent is to be described in terms that identify one or more aspects of participant performance that clearly show a high level of ability.

# 6.0 Relationships to National Skill Standards

## 6.1 Resources Used in Developing the Curriculum Competencies

The curriculum development effort included the use of several types of materials available to planners of academic curricula. Specifically, primary guidance was taken from:

- Society of Manufacturing Engineers (SME) documents *Curricula 2000* and *Curricula 2002* that outline the recommended content of any type of college-level program in fields related to manufacturing engineering, including the associate degree in manufacturing engineering technology
- recommended twelfth grade standards of the National Science Education Standards
- recommended twelfth grade standards of the National Council of Teachers of Mathematics
- standards and recommendations of the American Association of Teachers of Mathematics in Two-Year Colleges
- SCANS competencies developed by the U.S. Department of Labor Secretary's Commission on Achieving Necessary Skills
- several voluntary industry skill standards developed under the guidance of the National Skill Standards Board, particularly those called *Advanced High Performance Manufacturing*, *Computer Aided Drafting and Design (CADD)*, and *Machining*
- other industry skill standards such as:
  - Washington State Manufacturing Technology Standards as developed and promulgated by the Manufacturing Technology Advisory Group, Seattle, Washington, 1995
  - Machining and Metalworking Skill Standards as promulgated by the National Institute for Metalworking Skills (NIMS) and the National Tooling and Machining Association (NTMA)
  - *Setting the Standard— A Handbook on Skill Standards for the High Tech Industry*, Workforce Skills Project, American Electronics Association, Santa Clara, California, 1994
  - *National Photonics Skills Standard for Technicians*, Center for Occupational Research and Development, Waco, Texas, 1995
- *Sinclair Community College Bulletin*, 1995–96, Sinclair Community College, Dayton, Ohio

- *University of Dayton Bulletin*, 1995–96, University of Dayton, Dayton, Ohio
- selected competencies developed by the Miami Valley Tech Prep Consortium

Initial phases of the curriculum design identified over 800 competencies as appropriate for the associate degree in manufacturing engineering technology. These were arranged into a modular curriculum covering nine clusters of modules. Section 7.0 presents the details of the curriculum outline. Codes identify the various modules and subsequent discussions in this report refer to those codes. The clusters in the curriculum are:

1. Principles of Mathematics (MAF and MAA)
2. Principles of Science (SCF and SCA)
3. Humanities, Communication, and Teamwork (HCT)
4. Design for Manufacturing (PRP)
5. Production and Inventory Control (PIC)
6. Quality Management (QUA)
7. Manufacturing Processes and Materials (MPM)
8. Manufacturing Systems and Automation (SYS)
9. Enterprise Integration (EIN)

## 6.2 Impact of National Skill Standards on Curriculum Development

National skill standards have been developed by a variety of organizations. These standards create a set of workforce specifications that clearly describe the skills and knowledge desired by employers for workers in particular industries or types of occupations. The U.S. Department of Education and the U.S. Department of Labor funded twenty-two projects that were coordinated by the National Skill Standards Board. By their nature, the skill standards are directed to the general workforce.

One of the national standards, *Advanced High Performance Manufacturing*, is of particular relevance to the manufacturing engineering technology program being developed by this project.

Two others are somewhat related: *Computer Aided Drafting and Design and Machining*. Some industry-specific standards, such as photonics and electronics, have some manufacturing-related features.

Other standards are specific to occupations that are not closely related, such as automotive repair, bioscience, electrical construction, health care, human services, and hazardous materials management.

The *Advanced High Performance Manufacturing* standards cover 13 skill areas as listed in the chart in Figure 3. The total number of individual competencies over these 13 areas is 211. The project staff judged that the competencies are at a very basic level and of the type that would be expected of a person who operates a piece of production equipment. The skills in communication, math and measurement, workplace safety and health, computer use, workforce issues, workplace issues, and learning skills should have been developed in secondary school. If not, they could be developed with focused training on the job, in technical schools, or in community colleges. The skills in teamwork, quality assurance, blueprint reading, manufacturing fundamentals, business planning and operation, and product and process control would typically be post-secondary in nature and could be developed through technical schools, community colleges, or in some industrial training programs. However, a high-quality, industry-oriented Tech Prep program oriented to manufacturing should prepare a person with most such skills by the time of high school graduation.

The project staff intended that the proposed NCE/AME curriculum in manufacturing engineering technology include virtually all of the basic skills contained in the *Advanced High Performance Manufacturing* standards and significantly more. Its mathematics, science, communication, and technology coverage is far higher than found in the standards. Figure 3 shows the topics in the skill standards related to the curriculum modules in which such skills are to be developed by the participants.

A quite different comparison is made to the more focused *Computer Aided Drafting and Design and Machining* standards. These are meant to apply to a person who would be a specialist in these skill areas. They include a very comprehensive set of skills that normally would be developed in a college-level or apprentice training program that includes many hours of instruction and applied experience in the field. While the proposed NCE/AME curriculum includes elements of computer aided design and machining, it is not the intention to develop a skilled craftsperson in these areas. Therefore, the proposed curriculum includes only a small portion of the total competencies in these standards.

### 6.3 SCANS Competencies

Other sets of standards have a more general goal: the specification of skills needed in all jobs. Chief among these are the standards referred to as SCANS, developed by the U.S. Department of Labor Secretary's Commission on Achieving Necessary Skills. The commission

developed a set of five universal competencies that it said would be required of all workers. They are:

- **Interpersonal skills:** teamwork, negotiation, teaching, serving customers, and intercultural
- **Information:** acquire, evaluate, organize, interpret, and communicate
- **Allocating resources:** time, money, staff, space
- **Systems:** understand, monitor, correct, improve and design organizational and technological systems
- **Technology:** select, use, maintain, and troubleshoot

These five competencies were stated in a manner more focused on manufacturing in a document dated November 1, 1994, called *An Associate Degree in High Performance Manufacturing*, by Arnold H. Packer of the Johns Hopkins University Institute for Policy Studies. The result was a list of 22 standards, each of which includes a statement of competency, a list of performance factors that demonstrate competence, and a set of illustrative tasks that would be found in a variety of industrial settings.

Figure 4 is a comparison of the 22 manufacturing-oriented SCANS competencies with the modules in the proposed NCE/AME curriculum. It can be seen that all of the listed competencies are included in various modules in the proposed curriculum.

In addition, the proposed curriculum includes three features that promote the development of the SCANS competencies. The term “Guiding Principles” refers to a set of principles that are expected to be included in each module in the curriculum (refer to Section 4.0). Examples pertinent to this discussion of the relationships of the curriculum to national skill standards include: written and oral communication, teamwork, diversity, fair-mindedness, globalism, use of computers, and scientific method. Therefore, whereas communication and teamwork are expressly included in the modules or courses of the Humanities, Communication, and Teamwork cluster, they are also included in virtually every module in the program. In this way, communication and team building are seen as integrated parts of the entire program.

The proposed associate degree program includes a capstone experience at or near the end of each participant’s program. The participant would work as a member of a team on a real or very realistic project in which she or he must apply many of the competencies developed during the program. Problem solving, planning, data acquisition, and other skills would be brought to bear on a project to produce the design of a new manufacturing system or the improvement of an existing system. The

actual tasks performed would vary according to the specifics of the project. It is expected that the tasks would require the participant to apply many of the competencies reflected in the skill standards or the SCANS competencies.

Throughout the participant's program, all technical modules would include one or more transfer activities that require the participant to apply the competencies developed in the module in a different context. The same context would be used throughout, giving the participant an integrating manufacturing experience. In the initial development of the modules, the Integrating Manufacturing Experience is connected with Robotic Grippers, Inc. Participants would apply their competencies to a problem related to this hypothetical company that designs and produces a line of robotic grippers. Participants then see how all of their education ties together and how it relates to the kinds of situations they will face in their careers.

#### 6.4 Conclusion

This section has shown how the proposed associate degree curriculum in manufacturing engineering technology is related to the manufacturing-related national skill standards and to the SCANS competencies developed by the Secretary's Commission Addressing National Skills. It has shown how all of the SCANS competencies are covered and how the competencies in the *Advanced High Performance Manufacturing* skill standards are included. Subsets of the *Computer Aided Drafting and Design and Machining* standards are included in the proposed program. However, the technical depth and the scope and depth of coverage of mathematics and science in the proposed curriculum are significantly greater than called for in the national standards.

Some of the modules in the proposed program could be appropriate for inclusion in programs that are technical in nature but not specifically focused on manufacturing. Modules from mathematics, science, humanities, communications, and team building would be applicable to many fields. Industry-specific technologies could complete the program.

**Figure 3: Comparison of Competencies from Skills for Advance High Performance Manufacturing with NCE/AME Curriculum**

<b>Skill Area</b>	<b>How Addressed in NCM/AME Curriculum</b>
Communication and Teamwork	Guiding Principles, HCT Cluster, QUA01, EIN01
Math and Measurement	Mathematics Cluster, QUA03, QUA04, SCF03
Workplace Safety and Health	SCF02, Entire MPM Cluster addresses equipment safety concerns
Problem Solving	All PIC Modules, QUA01, QUA02, QUA03, PRP02, PRP04, PRP06, PRP07, EIN05
Quality Assurance	Entire Quality Management Cluster
Blueprint Reading	PRP01, PRP03, PRP08, MPM Cluster
Manufacturing Fundamentals	MAF02, QUA04, PIC Cluster, MPM Cluster, SYS03, SYS04, SYS05, SCA05, SCA06, SCA07
Business Planning and Operation	Entire Enterprise Integration Cluster, QUA01, PRP02
Computer Use	HCT02, PRP03, SYS02, SYS04, SYS05, EIN02
Product and Process Control	Entire PIC Cluster, Entire Quality Management Cluster
Workforce Issues	HCT11, HCT12, PSY229, Humanities Elective
Workplace Skills	HCT06, HCT11, HCT12, QUA01
Learning Skills	HCT11, Guiding Principles

<b>Figure 4: Comparison of SCANS Competencies with NCE/AME Curriculum</b>		
Standard		NCE/AME Modules
<b>Note:</b> The SCANS competencies are those used in An Associate Degree in High-Performance Manufacturing, by Arnold H. Packer. The original set of five SCANS competencies was expanded to 22 and particularized to manufacturing.		
1	Allocate Time: Identify relevant, goal-related activities, rank them in order of importance, allocate time to activities, and understand, prepare, and follow schedules.	HCT06, Entire PIC Cluster
2	Allocate Money: Use or prepare budgets, help to make cost and revenue forecasts, keep detailed records to track budget performance, and make appropriate adjustments.	EIN04, EIN05
3	Allocate Material and Facility Resources: Acquire, store, and distribute materials, supplies, parts, equipment, space, or final products in order to make the best use of them.	EIN01, QUA03, Entire PIC Cluster
4	Allocate Human Resources: Work with a team to identify and assess knowledge and skills and distribute work accordingly, evaluate performance and provide feedback.	HCT06, HCT12, PSY229, PRP04, PIC02, PIC08, QUA03
5	Acquire and Evaluate Information: Identify need for data, obtain them from existing sources or create them, and evaluate their relevance and accuracy.	All EIN Modules, All SCA Modules, SYS02, HCT10
5A	Understand and Comply with Legal Requirements: Be aware of regulations that apply to a specific firm/industry and be alert for situations that may be covered by these regulations.	EIN01, SCF02
6	Organize and Maintain Information: Work with a team to systematically organize, process, and maintain written or computerized records and other forms of information.	HCT02, HCT10, QUA02, QUA03, QUA04, EIN02, EIN05
7	Interpret and communicate Information: Select and analyze information and communicate the results to others using oral, written, graphic, or multimedia methods.	HCT02-10, PRP01, 03, 08, ENG Courses, SYS02, EIN02, EIN03, Guiding Principles
8	Use Computers to Process Information: Use computers to acquire, organize, analyze, and communicate information.	SYS02, SYS04, EIN02, HCT02, PRP03, Guiding Principles
9	Participate as a Member of a Team: Work cooperatively with others and contribute to the group with ideas, suggestions, and effort.	COM225, HCT06, Guiding Principles
10	Teach Others: Help others to learn.	PIC08, QUA02, QUA03

**Figure 4: Comparison of SCANS Competencies with NCE/AME Curriculum**

Standard		NCE/AME Modules
11	Serve Clients/Customers: Work and communicate with clients and customers to satisfy their expectations.	EIN03, QUA01, PRP02
12	Exercise Leadership: Communicate thoughts, feelings, and ideas to justify a position, encourage, persuade, convince, or otherwise motivate an individual or groups.	HCT06, HCT12, PIC05, COM225, PSY229, Guiding Principles
13	Negotiate to Arrive at a Decision: Work toward an agreement with customers (internal as well as external), vendors, or co-workers that may involve exchanging specific resources or resolving divergent interests.	HCT06, HCT12, PIC02, PIC06, PIC10, QUA03, EIN01, EIN03
14	Work with Diversity: Work well with men and women of different ages and with a variety of ethnic, social, or educational backgrounds.	HCT06, HCT12, Guiding Principles
15	Identify, Describe, and Work with Systems: Know how social, organizational, and technological systems work and operate effectively within them.	PIC01, PIC07, QUA01, QUA02, QUA03, PRP02, SYS02, HCT12, All EIN Modules
15A	Understand and Describe the Larger Social, Political, Economic, and Business Systems in which the Employee and the Firm Function: Understand the values that underlie business and personal ethics, government regulation, union-management relationships, environmental and equity concerns, and relationships with the community and its institutions.	HCT11, HCT12, SCF02, All EIN Modules, Guiding Principles
16	Monitor and Correct Performance: Distinguish trends, predict impact of actions on system operations, diagnose deviations in the function of a system/organization, and take necessary action to correct performance.	All PIC Modules, All QUA Modules, EIN01, EIN03, EIN04, EIN05, Capstone
17	Improve and Design Systems: Suggest modifications to existing systems to improve products or services and develop new or alternative systems.	HCT10, PRP01 thru PRP04, PRP08, All PIC Modules, QUA01, QUA02, QUA03, EIN05, Capstone
18	Select Technology: Contribute to a team judgment about a set of procedures, tools, or machines (including computers and their programs) that will produce desired results.	PRP02, PRP03, PRP04, MPM01, EIN03, Capstone
19	Apply Technology to Task: Understand the overall intent and perform the proper procedures for setting and operating machines, including computers and their programming systems.	All Modules in PIC, PRP, QUA, MPM and SYS Clusters
20	Maintain and Troubleshoot Technology: Prevent, identify, or solve problems in machines, computers, and other tools.	PIC07, PIC08, QUA02, QUA03, SYS04, SYS05

## 7.0 Curriculum Outline by Cluster

The curriculum for the manufacturing engineering technology associate degree program was developed under sponsorship of the National Science Foundation to prepare technicians to work primarily as a part of a production operations team. The curriculum is modular in structure. Each module is somewhat smaller than traditional courses offered in a quarter or semester system.

### 7.1 Entry Requirements for the Program

Participants entering the proposed manufacturing engineering technology program are required to have graduated from a quality secondary school program. Furthermore, they are expected to have met the twelfth grade competency levels espoused by the National Science Education Standards and the National Council of Teachers of Mathematics (refer to Appendix A).

Entering participants should be competent in mathematics topics, including what is commonly called algebra II, geometry, trigonometry, and basic statistics. Science competencies should include a strong foundation in the principles of physical science, mechanics, thermal science, and the fundamentals of inorganic chemistry. Refer to Appendix A for more details concerning entry requirements.

### 7.2 Basic Elements of the Curriculum

Instructional modules are organized within three basic clusters, six manufacturing clusters, an introductory module, and a major capstone experience. The use of clusters is intended to communicate an overview of the content of the program in major fields of study, so participants and employers will gain a general understanding of the nature of the program and the fundamental competencies that a graduate will possess.

Table 1 lists the major elements of the program.

<b>Table 1: Major Elements of the Program</b>
<p><b>Introduction to World-Class Manufacturing Module</b></p> <p><b>Basic Clusters</b></p> <ol style="list-style-type: none"> <li>1. Principles of Mathematics</li> <li>2. Principles of Science</li> <li>3. Humanities, Communication, and Teamwork</li> </ol> <p><b>Manufacturing Clusters</b></p> <ol style="list-style-type: none"> <li>4. Design for Manufacturing</li> <li>5. Production and Inventory Control</li> <li>6. Quality Management</li> <li>7. Manufacturing Processes and Materials</li> <li>8. Manufacturing Systems and Automation</li> <li>9. Enterprise Integration</li> </ol> <p><b>Capstone Project</b></p>

### Integrating Manufacturing Experience and the Capstone

The curriculum outline lists for each cluster the set of instructional modules containing the primary competencies to be mastered by participants as they work through the cluster. The sequencing of modules in the curriculum is discussed separately. The modular structure allows participants to progress through the program in many different paths, provided that prerequisite competencies have been developed.

Throughout the curriculum, in each manufacturing module and in appropriate modules in the basic clusters, the participant will follow the development and production of a specific product through an integrating manufacturing experience containing learning tasks related to the product.

The capstone experience is a major project at the end of the participant's program, conducted in cooperation with an industry, that serves to integrate and reinforce all of the competencies participants develop in the curriculum.

### Notes on Terminology Used in the Curriculum Outline

1. **Clusters:** The curriculum outline is organized into nine clusters for developing instructional materials. Each cluster contains a set of modules related to a particular field of knowledge.
2. **Module designations:** Each module within each cluster carries a designation consisting of a three-letter code and a two-digit number. The letter codes are:

- **MAA:** Mathematics—Advanced (College Level)
- **SCA:** Science—Advanced (College Level)
- **HCT:** Humanities, Communication, and Teamwork
- **PRP:** Design for Manufacturing
- **PIC:** Production and Inventory Control
- **QUA:** Quality Management
- **MPM:** Manufacturing Processes & Materials
- **SYS:** Manufacturing Systems and Automation
- **EIN:** Enterprise Integration

The beginning module (Introduction to World-Class Manufacturing) and the ending module (Capstone Project) both relate to the entire manufacturing program and carry the letter code MFG.

3. **EHI—Equivalent Hours of Instruction:** The pedagogy for the program is based on the constructivist model in which participants learn primarily by engaging in authentic learning tasks; real world activities requiring the use of the competencies to be developed in the module. The tasks are best conducted in settings that are more like laboratories or project rooms than traditional classrooms. The use of the lecture mode of instruction is discouraged in favor of having the faculty member act as a facilitator of the learning process.

It is inappropriate to refer to the size of a module in terms such as “quarter hours” or “semester hours” because such terms typically refer to a set number of lecture hours per week for a full quarter or semester. To allow some measure of the size and scope of a module, the term EHI refers to the amount of time in a traditional lecture mode that an experienced instructor would require to cover the material in the module. Using this definition, it could be said that 10 EHI are approximately equivalent to one quarter hour. This aids the judgment of how much material is appropriate to be included in an associate degree program.

4. **Module list:** Appendix B is a listing of all modules arranged by cluster. Note that within the Humanities, Communication, and Teamwork cluster (HCT), there are six courses taken from the general offerings of the college. They are listed at the end of Appendix B and in the introduction to the HCT cluster that follows here. The courses are illustrated to be three quarter credits each in the more traditional arrangement found in colleges on the quarter system. The use of courses is based on the assumption that the entire college would not be organized in the modular format when the Manufacturing Engineering Technology program is initiated.

These courses would be taken by students throughout the college. As the movement to a college-wide modular takes hold, it is expected that these courses would also be offered as modules that add to the flexibility of a participant's program.

The course numbers and titles conform to those used currently at Sinclair Community College in Dayton, Ohio. Each college would specify similar courses from its offerings.

5. **Curriculum arrangement:** Ideally, participants will navigate through the curriculum in an individualized manner. Whenever the prerequisite competencies for a given module have been developed, the participant should be able to enroll in that module. Because the modules are typically much smaller than traditional courses, they can be completed at any time that an appropriate faculty facilitator and facilities are available. The participant should not be limited to starting and ending modules according to traditional quarters or semesters. Section 8.0 of this report presents a program plan that has the character of a critical path PERT chart. Each participant would work with a counselor to decide which modules or courses should be taken at a given time.

### 7.3 Module List by Cluster

Presented here are all 67 modules to be included in the curriculum for the Manufacturing Engineering Technology program. They are listed here by cluster in the order shown in Table 1 and in Appendix B. Note that the two MFG modules, Introduction to World-Class Manufacturing and the Capstone Project, are the first and last modules listed.

Each cluster begins with a description of the major goals of the cluster and how the module competencies relate to the work of a manufacturing engineering technician.

Each module listing includes the following:

- the title, the module designation number
- the size of the module in equivalent hours of instruction (EHI)
- a brief description of the nature of the module
- a list of the competencies to be developed in the module
- a list of the prerequisites

Introduction to World-Class Manufacturing (MFG01) [15 EHI]

This module is designed to be one of the earliest completed by the participant. It is presented in the form of a "mini" manufacturing experience in which the processes involved in the design and production of a simple product are demonstrated in a short time period. As the

participant participates in this experience, she or he encounters essential elements from many future modules.

The participant will gain a basic understanding of the entire curriculum and, as a consequence, an understanding of the essential elements of the product planning, product design, process planning, production planning, and production operation cycle required to develop and produce a product.

This module will help the participant understand the objectives of the course of study and the nature of the work to be done as a manufacturing engineering technician after completing the program. It also introduces the participant to the concept of the integrating manufacturing experience, so the participant can better understand the relationship among all of the modules in the program.

*Competencies Developed in This Module:*

- Describe the role of the manufacturing engineering technician within the product realization process and in relation to the entire curriculum.
- Identify and describe components of the product realization process, including product conceptualization, sales and marketing, product design, process planning, production planning, inventory planning and control, manufacturing processes, quality, distribution, customer service, and removal of the product from the marketplace.
- Describe the interactions among the components of the product realization process.
- Apply the product realization process to a specific product.
- Explain the importance of teamwork in a manufacturing operation.
- Compare previous learning experiences to the learning experience in this contextual, activity-based, competency-based, industry-verified, integrated module.
- Describe the enterprise management process (including supply chain management, manufacturing information systems, customer satisfaction, financial management, performance measures, and enterprise management) and how the manufacturing engineering function interfaces with each component of this process.
- Identify and describe essential elements of world class manufacturing enterprises, including supply chain management, lean manufacturing, just-in-time manufacturing, concurrent engineering, continuous quality improvement, and computer integrated manufacturing.

It is highly recommended that two other modules, Professional Development (HCT11), and Principles of Manufacturing Processes (MPM01), be completed concurrently with the Introduction to World-Class Manufacturing module.

## Principles of Mathematics Cluster (MAA)

The set of modules in the Mathematics Cluster is designed to develop the competencies in mathematics expected of a manufacturing engineering technician. These competencies are expected of participants in many fields and it is likely that these modules will be included within courses offered for a broad array of participants. Participants taking these modules are expected to have developed the competencies in the twelfth grade standards of the National Council of Teachers of Mathematics (NCTM), including the principles of algebra, geometry, trigonometry, and basic statistics. The college level modules listed here extend this background into college-level precalculus, probability and statistics, and the basics of calculus. Some modules list prerequisites with the designation in the form MAF09, indicating foundation competencies normally obtained in secondary school. An appendix lists these modules.

### Modules

College Geometry (MAA01) [12 EHI]

Participants build on the basic competencies of geometry developed in prior learning and apply new competencies in authentic applications. The primary emphasis is on three-dimensional figures as are typically encountered in manufacturing of real components and systems.

*Competencies Developed in This Module:*

- Construct complex three-dimensional geometric figures.
- Interpret three-dimensional drawings of solid objects by computing the values of key features such as lengths, angles, radii, points of intersection, points of tangency, area, and volume.

**Prerequisites:** Three Dimensional Figures (MAF09), Coordinate Geometry (MAF10), College Algebra Applications (MAA14)

Vector Analysis (MAA02) [10 EHI]

Participants learn the definition of vectors, learn how to mathematically manipulate them, and apply them to a variety of real physical systems.

*Competencies Developed in This Module:*

- Define vectors and give examples of meaningful applications from participants' personal experience.
- Represent vectors graphically.
- Add vectors graphically.
- Break down vectors into X-Y components.
- Add vectors algebraically.
- Recognize and apply vectors as solutions to real problems.

**Prerequisite:** College Algebra Applications (MAA14)

Further Applications of Trigonometry (MAA03) [12 EHI]

This module builds on the fundamentals of trigonometry participants developed in prior learning and applies new competencies to more complex real world problems, including some that are pertinent to manufacturing.

*Competencies Developed in This Module:*

- Solve triangles using law of sines and cosines.
- Define the complex numbers. Be able to perform basic operations on them graphically and algebraically.
- Use trigonometric functions to solve various types of problems.
- Explore periodic real world phenomena using the sine and cosine functions.

**Prerequisite:** College Algebra Applications (MAA14)

Precision, Accuracy, and Tolerance (MAA04) [10 EHI]

A manufacturing engineering technician must have a thorough understanding of the importance of precision and accuracy. This module gives participants experience in identifying the importance of tolerances based on customers' needs. In addition, participants use a variety of measuring devices to learn about precision and accuracy.

*Competencies Developed in This Module:*

- Use correctly the terms precision, accuracy, and tolerance in discussing customer requirements and alternative approaches to meeting those requirements.
- Describe the purposes and demonstrate the process of calibration.
- Identify specific criteria to consider when selecting testing instruments.
- Communicate concerns of various departments in a manufacturing environment.
- Explain benefit/cost analysis and the 10:1 rule in decision making.
- Justify a decision in a clear, concise memo.
- Explain the purpose of rounding.
- Apply rounding rules involving approximate numbers that are multiplied, divided, added and/or subtracted.
- Determine significant digits of a given number.
- Determine the effects of rounding and uncertainty on the precision and accuracy of a simple process.

**Prerequisite:** College Algebra Applications (MAA14)

Probability, Sampling, and Hypothesis Testing (MAA06) [12 EHI]

Probability is learned as a complement to other statistics-related modules. Fundamental principles of uncertainty, combinations, and permutations are learned through practical, realistic applications.

*Competencies Developed in This Module:*

- Use summary techniques such as box plots, stem and leaf plots, and percentiles to analyze and interpret data sets.
- Use the techniques of sampling and recognize the nature of variability in sample data, including the use of computer analysis tools.
- Using sample data, make predictions based on the foundational principles of the central limit theorem.
- Using normal distribution, analyze error and determine a significance level based upon risk with which the user is comfortable.
- Analyze variability in a process using hypothesis testing.

**Prerequisite:** College Algebra Applications (MAA14)

Statistical Distributions (MAA07) [12 EHI]

Statistical Distributions introduces participants to the analysis of statistical distributions, including: collecting data, using graphical calculators, and solving real world problems. In addition, participants learn how to determine a product warranty period using data that illustrate normal distribution.

*Competencies Developed in This Module:*

- Create and interpret exponential, uniform, and normal distributions.
- Apply the concept of random variables to generate and interpret probability distributions, including uniform, normal, and exponential.
- Construct an exponential distribution graph from collected data and use the graph to formulate a description regarding the behavior of the data.
- Graph and analyze a learning curve in order to make a decision.
- Construct a histogram representing a uniform distribution; determine the validity of “systems” to predict random events.
- Describe the effect of changing the mean and standard deviation for uniform and normal distributions.
- Determine a product warranty period using data which illustrate a normal distribution.

**Prerequisite:** Probability, Sampling, and Hypothesis Testing (MAA06)

Statistical Experiments (MAA09) [15 EHI]

Participants gain competence in sampling, making inferences, and testing hypotheses by designing and conducting statistical experiments with realistic data.

*Competencies Developed in This Module:*

- Use sound sampling techniques and data analysis to make repeatable, defensible inferences.
- Solve real world problems by designing and conducting factorial and fractional factorial experiments.
- Use analysis of variance (ANOVA) to interpret experimental results.
- Graphically display outcomes using regression analysis to communicate the recommended action based on the experiment.

**Prerequisite:** Statistical Distributions (MAA07)

Differentiation (MAA11) [12 EHI]

Participants develop the ability to use analytical techniques to describe and analyze real problems that involve rates of change, maxima, and minima. Participants discover the concept of the limit of a function as it is used to define the differential. They also apply the process of differentiation.

*Competencies Developed in This Module:*

- Demonstrate a conceptual understanding of the derivative as a rate of change.
- Evaluate limits of a function and find the derivative of a function.
- Solve applications of minima, maxima, and related rate problems using graphing and algebraic methods.
- Find relative maximum, minimum, and point of inflection of a given function and sketch its graph.

**Prerequisite:** College Algebra Applications (MAA14)

Integration (MAA13) [12 EHI]

Participants discover the concept of integration by setting up and solving real problems. Applications to area problems and situations in which the cumulative effect of a variable is needed are used to develop the skill of finding differentials and antiderivatives of functions.

*Competencies Developed in This Module:*

- Find the differential and antiderivative of a given function.
- Demonstrate a conceptual understanding of integration as the cumulative effect of a variable.
- Evaluate the definite integral and solve area problems.

**Prerequisite:** Differentiation (MAA11)

College Algebra Applications (MAA14) [10 EHI]

This module introduces the activity-based, competency-based instruction in mathematics that characterizes all the modules in the curriculum. It reviews competencies that participants are expected to have developed from secondary school or from other instruction and applies them in a variety of authentic learning tasks. It should be the first mathematics module completed.

*Competencies Developed in This Module:*

- Transfer the function concept to meaningful, real world experiences.
- Verify the capability of algebraic functions to model real world technical applications.
- Demonstrate the ability to formulate algebraic functions to model authentic situations with realistic data.
- Recognize and demonstrate the synergy between theoretical mathematics and empirical discovery and design.
- Apply the scientific method (collect and analyze data in order to predict) using functions to solve real world problems.

**Prerequisites:** Basic Statistical Variation (MAF13).

## Principles of Science Cluster (SCA)

Each of the modules in science is designed to develop systematic thinking skills, including the ability to formulate questions and plan investigations, collect and interpret data, formulate and revise explanations and models using logic and evidence, analyze alternative explanations and models proposed by others, communicate and defend scientific conclusions.

In addition, each module develops specific concepts and principles that are applicable to a wide variety of situations and teaches participants to apply those concepts and principles to manufacturing-related tasks.

Participants taking these modules are expected to have developed competencies equivalent to the twelfth grade standards of the National Science Education Standards (NCES). Included are the principles and methods of science, safety and environmental precautions, basic physics mechanics, basic thermal science, and basic chemistry. Some modules list prerequisites with the designation in the form of SCF06, indicating foundation competencies normally obtained in secondary school. A listing of these modules is included in Appendix A.

## Modules

Rotational Motion and Torque (SCA01) [10 EHI]

Participants will build on the fundamentals of mechanics to learn how to analyze the performance of rotating equipment. Emphasis is on describing the character of rotational motion, how the motion is related to the torque acting upon it, and the inertia of the rotating components.

*Competencies Developed in This Module:*

- Use the rotational kinematic equations to describe angular position, angular velocity, and angular acceleration of a rotating object.
- Determine the center of gravity and moments of inertia of solid objects.
- Calculate the centripetal acceleration for an object with angular motion in a horizontal or vertical circle and apply the centripetal force to a variety of situations.
- Apply an understanding of torque, rotational motion, and moments of inertia in analyzing manufacturing operations, such as cutting parts on a lathe.

**Prerequisite:** Work and Energy (SCF05)

Momentum (SCA02) [10 EHI]

In this module, participants analyze the changes in momentum of devices as they are acted upon by impulses, using a variety of equipment, some of which is related to manufacturing processes.

*Competencies Developed in This Module:*

- Use the concepts of impulse and momentum to predict the motion of objects after collisions.
- Apply momentum in designing and analyzing safety equipment for manufacturing processes.

**Prerequisite:** Rotational Motion and Torque (SCA01)

Vibrations and Waves (SCA03) [10 EHI]

Participants study mechanical equipment with regard to vibrations that develop as a result of varying forces. Participants will discover how vibration and waves behave and how they are related to the mass, materials, and geometry of machine components.

*Competencies Developed in This Module:*

- Apply an understanding of resonance and damping to analyze and correct problems related to packaging, machine operations, or similar areas.
- Demonstrate an understanding of how waves (including sound and seismic waves, waves on water, and light waves) carry energy and interact with matter.

- Apply an understanding of sound in interpreting OSHA regulations regarding sound levels.

**Prerequisite:** Work and Energy (SCF05)

Optics (SCA04) [10 EHI]

Light and other kinds of rays are examples of electromagnetic waves. They are useful in sensing, measurement, communication, and some types of materials-processing systems. Participants will discover the principles that govern the generation and propagation of waves and the performance of optical equipment.

*Competencies Developed in This Module:*

- Discuss and apply the properties of mirrors and lenses to optical systems and instruments.
- Apply the principles of interference and diffraction to analyze the behavior of light through apertures.
- Demonstrate an understanding that electromagnetic waves (including radio waves, infrared, visible light, ultraviolet, x-rays and gamma rays) result from the acceleration of charged objects and deliver energy in packets.
- Apply an understanding of light and optics in the workplace, dealing with issues such as illumination, fiber optics, optical sensors, etc.

**Prerequisite:** None

Basic DC Circuits (SCA05) [10 EHI]

Basic DC Circuits helps participants gain an understanding of resistance, voltage, and current in series and parallel direct current (DC) circuits. In addition, participants learn about the application of these concepts for instrumentation and other practical purposes.

*Competencies Developed in This Module:*

- Read circuit diagrams, breadboard DC circuits, and use the variable DC power supply.
- Use Ohm's law to calculate resistance, voltage, and current, assigning correct units.
- Use the digital multimeter (DMM) to measure resistance, voltage, and current in DC circuits.
- Analyze series DC circuits using Kirchhoff's voltage law (KVL).
- Analyze parallel and series-parallel circuits.

Magnetism and AC Circuits (SCA06) [10 EHI]

Participants will work with motors, generators, and alternating current (AC) circuits to develop the ability to analyze their performance and to describe the principles on which they operate.

*Competencies Developed in This Module:*

- Demonstrate an understanding of the relationship between electricity and magnetism, including the role of these forces in electric motors and generators.
- Describe the operation and principle of DC generators and motors.
- Describe the operation and principle of AC generators and motors.
- Analyze the behavior of resistors, capacitors, and inductors in AC circuits.
- Apply troubleshooting techniques to AC circuits.

**Prerequisite:** Basic DC Circuits (SCA05)

Fundamentals of Electronics (SCA07) [10 EHI]

Electronic devices, circuits, and systems are used to control numerous kinds of products and commercial and industrial equipment. Participants will observe the behavior of electronic devices and circuits, formulate the principles which govern their operation, and troubleshoot systems containing such devices.

*Competencies Developed in This Module:*

- Apply troubleshooting techniques to analog circuits.
- Demonstrate proficiency in electronics fundamentals.
- Demonstrate an understanding of semiconductor materials, diodes, bipolar junction transistors, V-I characteristics, and operational amplifiers.
- Apply principles of electronics in operating and troubleshooting industrial machines.

**Prerequisite:** Magnetism and AC Circuits (SCA06)

Organic Chemistry (SCA08) [10 EHI]

Building on prior knowledge of the fundamentals of chemistry, participants will study the structure, nature, and behavior of organic substances containing carbon atoms. Applications will emphasize plastics, polymers, oils, plants, and some kinds of foods.

*Competencies Developed in This Module:*

- Demonstrate how carbon atoms can bond to one another and to hydrogen, nitrogen, and halides in chains, rings, and branching networks.
- Identify functional groups and how they relate to properties of organic materials.
- Analyze a simple mixture by separating and identifying its components.
- Identify common polymers and their applications.
- Correlate polymer structures to their properties and uses.
- Recognize and describe common routes to polymer production.
- Demonstrate awareness of “cradle-to-grave” environmental issues.

**Prerequisite:** High school chemistry or equivalent

The Behavior of Fluids (SCA09) [10 EHI]

Participants will explore how fluids are used in hydraulics, pneumatic devices, and typical industrial and commercial fluid-handling systems. They will formulate the governing relationships among important variables and apply those relationships to predict the behavior of the fluids.

*Competencies Developed in This Module:*

- Apply the principles of fluid mechanics to both viscous and non-viscous flow of fluids.
- Demonstrate an understanding of fundamental pneumatic principles.
- Demonstrate an understanding of fundamental principles of vacuum.
- Demonstrate an understanding of fundamental hydraulic principles.

Useful and Hazardous Radiation (SCA10) [10 EHI]

Measurement devices and materials processing systems use many forms of radiation. Other forms may be hazardous to health and safety. Participants will develop competencies that demonstrate their ability to use radiation properly and safely.

*Competencies Developed in This Module:*

- Demonstrate an understanding of the nature of the nuclear force and its role in fission and fusion.
- Describe the characteristics of radioactive decay.
- Discuss applications of radiation to nondestructive testing.

## Humanities, Communication, and Teamwork (HCT)

In this cluster the participant will examine the challenges faced by humankind in the evolution of our technological world. The participant will confront the philosophical and ethical dimensions of the evolving technological environment. He or she will encounter opportunities to interact in an interpersonal setting to optimize his/her communication skills so as to maintain a productive work environment. Lastly, the learner will have many opportunities to work successfully in a team environment that capitalizes on group synergy.

### **Prerequisite knowledge required:**

The learner should possess the following basic skills:

- proficiency in the language of instruction
- working knowledge of world geography
- awareness of the need for career planning

**Note:** Participants are expected to complete the following requirements from the general college offerings.

- Four semester credits or six quarter credits of college-level English composition.
- Six semester credits or nine quarter credits of humanities and social science courses. The social science and humanities courses should be selected from those pertinent to a career in manufacturing, as defined by the director of the manufacturing engineering technology program.
- Two semester credits or three quarter credits in the fundamentals of communication, preferably with an emphasis on small group and interpersonal communication.

## Modules

Computer Skills (HCT02) [15 EHI]

Participants enhance their computer skills in the areas of document preparation, the use of spreadsheets, basic programming, the creation of databases, and the generation of presentation graphics. They learn to communicate by e-mail and to use the Internet effectively to acquire information. Manufacturing engineering technicians are expected to demonstrate such skills.

*Competencies Developed in This Module:*

- Operate personal computers and use a current operating system such as Windows® or Macintosh.
- Prepare documents using a comprehensive integrated package such as Microsoft® Office (word processing, spreadsheets, databases, and presentation graphics).
- Communicate using e-mail.
- Use the World Wide Web to acquire information on a variety of topics pertinent to manufacturing.
- Write basic computer programs using QBASIC, Visual BASIC, C, C++, or Visual C.

Teamwork

(HCT06)

[10 EHI]

In order to gain the knowledge and skills necessary to be an effective team member, participants explore and analyze the principles of good teamwork. Participants utilize teamwork principles to encourage effective teamwork and explain and implement an effective problem-solving process within a team.

*Competencies Developed in This Module:*

- Name the four stages of team development.
- Identify the elements of each team development stage.
- Evaluate team performance based on team principles.
- Utilize teamwork principles to encourage effective team work.
- Explain and implement an effective problem-solving process within a team.

**Prerequisite:** Instruction in the fundamentals of interpersonal communication

Preparation of Letters and Memoranda

(HCT08)

[10 EHI]

Participants build on their fundamental composition skills to develop competencies in preparing technical communications as employed within industrial organizations.

*Competencies Developed in This Module:*

- Demonstrate the plan, write, revise writing process in technical communication.
- Apply effective methods of writing letters and memoranda in the workplace.

- Practice accepted principles of technical writing.

**Prerequisite:** This module is designed for participants who have completed the standard freshman composition sequence.

#### Preparation of Technical and Research Reports (HCT10) [10 EHI]

This module helps participants develop the ability to prepare comprehensive technical reports as are expected of manufacturing engineering technicians to document results of technical projects.

*Competencies Developed in This Module:*

- Demonstrate the ability to plan and prepare effective reports of technical analyses, designs, laboratory test results, and research on technical topics that include accepted formats and standards of documentation.

**Prerequisite:** All English composition courses

#### Professional Development (HCT11) [15 EHI]

Professional Development focuses on important job skills other than technical skills. Participants learn the significance of professional organizations, time-management techniques, and goal-setting. The individual portfolio, developed in the Transfer Activity, provides participants with a useful tool as they begin their manufacturing engineering technology program and as they search for relevant jobs.

*Competencies Developed in This Module:*

- Identify employability skills such as punctuality, professional appearance, professional demeanor, and basic technical knowledge.
- Summarize the need for lifelong learning, including continuing education and an awareness of legal and cultural shifts.
- Interpret the importance of anticipating and responding to change.
- Identify and apply individual learning styles.
- Explain the importance of being active in professional societies and associations, and demonstrate a willingness to join such a group.
- Implement time-management techniques to prioritize responsibilities and schedule tasks.

Tools for the Future (HCT12) [30 EHI]

This unique module gives the participants the tools and the confidence to work well with all associates and to perform as a high-performance employee in a manufacturing organization.

*Competencies Developed in This Module:*

- Discuss the essential themes and concepts presented in the books *The Seven Habits of Highly Effective People*, by Stephen Covey and *The Goal*, by Eliyahu M. Goldratt.
- Explain the basic concepts of the theory of constraints and apply them to the work environment of a manufacturing enterprise.
- Apply the tools described in the book by Covey to real situations requiring collaboration, cooperation, and communication among associates on the job.
- Apply the tools described in the book by Goldratt and demonstrate appropriate logical thinking processes used in problem solving.

**Prerequisite:** Teamwork (HCT06)

Design for Manufacturing Cluster (PRP)

As a member of a product realization team, the manufacturing engineering technician may participate in the process of analyzing customer needs, volume demands, and market requirements and conceptualizing and designing a product or service to meet those needs, demands, and requirements. Such a team may be simultaneously designing the processes to produce and distribute the product or service in the most productive and least costly manner possible and to launch the product into production.

Modules

Drawing and Sketching (PRP01) [10 EHI]

Participants develop the ability to prepare accurate technical drawings of mechanical components with dimensions necessary to produce the component. Standard industry techniques are emphasized.

*Competencies Developed in This Module:*

- Identify basic key terms and concepts related to freehand sketching.
- Communicate abstract ideas clearly on paper in a visual language so that concepts are conveyed with minimal verbal explanation.
- Provide a clear visual and verbal narrative that articulates intended ideas, concepts, functions, and images for the purpose of describing and using the end product.

- Create and interpret multiview (orthographic) engineering drawings including three views, planar projections, section views, and line types.
- Create and interpret dimensioning and notes including placement and symbols.
- Create and interpret working engineering drawings including standard format, title block, change control (revision control), scale, bill of materials, and assembly drawings.
- Explain GD&T concepts and reasons why GD&T is important for assembly and manufacturing.
- Identify GD&T basic terminology and how it is used on an engineering drawing.
- Interpret basic GD&T symbols and explain how they affect part geometry.
- Identify when it is appropriate to use sketching, drafting, and GD&T during the phases of the product development cycle.

**Prerequisites:** Participants should have some experience with geometry or trigonometry, and drawing lines, curves, circles, and angles.

Conceptual Design (PRP02) [15 EHI]

Conceptual Design introduces participants to the phases of the product realization process (PRP), emphasizing areas in which a manufacturing technician would be most closely involved. Participants take part in product development teams; identify customer needs; derive functional requirements, design requirements, and design criteria; develop and present conceptual designs; and identify appropriate manufacturing processes for a design.

*Competencies Developed in This Module:*

- Participate effectively on a Product Development Team.
- Articulate the essential characteristics of a Product Development Team.
- Identify customer needs.
- Derive functional requirements, design requirements, and design criteria based on customer requirements.
- Develop conceptual designs based on functional requirements, design requirements, and design criteria.
- Present conceptual designs in the form of sketches and written narration that show how specifications have been met.
- Identify appropriate manufacturing processes for a particular design.
- Perform a standard decision analysis.

- Present a final product design, including its manufacturing process, to a design process review committee.
- Respond effectively to a design review committee's questions and constructive criticism relating to conceptual design.
- Describe the Design Failure Modes and Effects Analysis (DFMEA) process.
- Recognize a standard DFMEA form and explain how it is completed.
- Describe the Process Failure Modes and Effects Analysis (PFMEA) process.
- Recognize a standard PFMEA form and explain how it is completed.

**Prerequisites:** Drawing and Sketching (PRP01), Principles of Manufacturing Processes (MPM01), Customer Satisfaction (EIN03)

Computer Aided Design (PRP03) [15 EHI]

Participants learn how to use computer aided design (CAD) software to prepare accurate drawings of mechanical components in three dimensions along with all necessary dimensions and the basic symbols of geometric dimensioning and tolerancing (GD&T).

*Competencies Developed in This Module:*

- Demonstrate basic skill in the production of product design drawings as represented in three dimensions in a CAD system.
- Interpret product designs represented in a CAD system in terms of the expected geometrical features of the product and apply GD&T symbology.

**Prerequisite:** Drawing and Sketching (PRP01)

Product Development and Testing (PRP04) [15 EHI]

Participants gain skills that make them effective members of Product Development Teams, with special emphasis on the linkages between design and manufacturing requirements.

*Competencies Developed in This Module:*

- Demonstrate the Product Realization Process and its relationship with Design for X (safety, manufacture, assembly, environment), prototype testing, rapid prototyping, and rapid manufacturing.
- Explain and demonstrate the roles of various members of a product development team as they relate to effective teamwork, communication, and leadership, with particular emphasis on the role of the manufacturing engineering professional.

- Apply Design for X techniques to ensure that a cost-effective product exhibits satisfactory safety, durability, reliability, maintainability, manufacturability, and minimum environmental impact over the life cycle of the product.
- Analyze and assess the effectiveness of a design over its lifecycle.
- Plan and implement rapid prototype and rapid manufacturing processes and show the benefit of these techniques on the design iteration cycle.
- Plan and implement tests to assess design and manufacturing effectiveness.

**Prerequisites:** Conceptual Design (PRP02), Computer Aided Design (PRP03)

Statics (PRP06) [20 EHI]

Participants apply the fundamentals of physics mechanics to practical problems requiring the determination of forces and moments on structures and machine components.

*Competencies Developed in This Module:*

- Analyze forces and moments on structures and components of structures.
- Determine the location of the centroid and moment of inertia for areas and volumes.
- Use the concepts of equilibrium to solve for unknown forces and moments.
- Use the principles of friction to solve problems with significant frictional forces.

**Prerequisite:** Equilibrium: Newton's First Law (SCF06)

Strength of Materials (PRP07) [20 EHI]

In this module, participants develop competencies in the fundamentals of stress analysis, as applied to manufacturing processes and manufacturing machinery.

*Competencies Developed in This Module:*

- Analyze the effects of forces and moments on structures and components of structures to determine the resulting stresses and deflections.
- Analyze components and structures for direct axial stress, direct shear stress, torsional shear stress, and bending stress in beams.

- Analyze columns to determine allowable axial load to preclude buckling.
- Analyze components and structures to determine deflections and deformations due to direct axial loading, bending, torsional shear, and thermal effects.

**Prerequisites:** Statics (PRP06), Metallic Materials (MPM03)

Geometric Dimensioning and Tolerancing (PRP08) [15 EHI]

In Geometric Dimensioning and Tolerancing, participants work with drawings and actual parts to become familiar with the international system of symbols used to articulate and understand design requirements. The ASME/ANSI Y14.5 standards for geometric dimensioning and tolerancing (GD&T) are used.

*Competencies Developed in This Module:*

- Explain the importance of applying geometric dimensioning and tolerancing (GD&T) early in the product realization process.
- Define the functionality of GD&T systems to determine assemble-ability of parts.
- Examine advantages and disadvantages of appropriate measurement methods, and interpret measurement data regarding quality of conformance.
- Convert simple traditional drawings to a GD&T format that meets ANSI/ASME Standard Y14.5, including establishing and justifying datums.

**Prerequisites:** Drawing and Sketching (PRP01), Principles of Manufacturing Processes (MPM01)

Production and Inventory Control Cluster (PIC)

The manufacturing engineering technician will support and participate on teams that plan, analyze, and control the production of products from the acquisition of raw materials through the production and distribution of the products to customers. Included will be the planning and implementation of facilities for production, the specification of manufacturing processes, the effective management of inventory, and the implementation of lean, world-class manufacturing concepts.

## Modules

### Principles of Production and Inventory Control (PIC01) [15 EHI]

Participants describe types of inventory and their costs, how they relate to manufacturing operations, and techniques for inventory management. By comparing the concepts of MRP/EOQ techniques with the theory of constraints, just-in-time, and lean manufacturing, participants investigate the impact of each on profitability.

#### *Competencies Developed in This Module:*

- Describe and discuss the types of inventory and their costs, how they relate to manufacturing operations, and techniques for inventory management.
- Compare the concepts of MRP/EOQ techniques with the theory of constraints, just-in-time, and lean manufacturing and discuss their impacts on profitability.
- Identify and discuss just-in-time, one-piece flow, lean manufacturing, theory of constraints, and MRP.

### Manufacturing Resource Planning (PIC02) [15 EHI]

Participants learn procedures for managing materials in a lean manufacturing environment.

#### *Competencies Developed in This Module:*

- Describe and explain the role, objectives, structure, methods, advantages, and limitations of materials management techniques used in production systems.
- Apply material requirement planning processes, using bills of material, the description of work centers involved, safety stock, and master schedules for a production system.

### Introduction to Just-in-Time (JIT) (PIC06) [10 EHI]

Participants learn the basic concepts of just-in-time and the importance of just-in-time tools for improving production processes. Through hands-on activities, participants experience the difference between just-in-time and a traditional manufacturing approach.

#### *Competencies Developed in This Module:*

- Describe throughput and calculate throughput for a manufacturing process.

- Identify the specific tasks that comprise a given manufacturing process.
- Classify tasks as value added or non-value added.
- Explain the effects of small lot size on a manufacturing process.
- Describe the relationships among cost, quality, and time in a manufacturing process.
- Identify potential sources of waste in a manufacturing process.

**Prerequisite:** Principles of Production and Inventory Control (PIC01)

Process Flow and Lead Time Reduction (PIC07) [9 EHI]

Through guided discovery, participants learn the importance of effective work flow and short lead times in manufacturing operations, as well as how to identify and eliminate waste. This module also gives participants the opportunity to analyze setups and changeovers and to design processes for rapid setups and changeovers.

*Competencies Developed in This Module:*

- Describe the importance of effective work flow and short lead times in manufacturing operations.
- Use process flow and lead time analysis and reduction techniques.
- Identify and eliminate waste in manufacturing systems.
- Analyze setup and changeover procedures.
- Design processes for rapid setups and changeovers.
- Use the “Seven Deadly Sins of Waste” model to eliminate waste in a manufacturing process.

**Prerequisite:** Introduction to Just-in-Time (JIT) (PIC06)

Consistent Work Methods and Build to Demand (PIC08) [10 EHI]

This module introduces participants to two major concepts in modern manufacturing: achieving and applying consistent work methods and “build to demand.” Participants design standardized work methods, processes, and motions. They design a work cell, a powerful tool for implementing “build to demand,” and propose a process flow to meet customer expectations.

*Competencies Developed in This Module:*

- Design standardized work methods (routers), processes, and motions in a cell environment.

- Considering materials, routing, lot sizes, shop processes, scrap rates, etc., propose a product process flow to meet customer expectations.

**Prerequisite:** Introduction to Just-in-Time (JIT) (PIC06)

Kanban and Pull Systems (PIC10) [10 EHI]

By applying kanban and pull systems principles and tools to real world problems, participants experience firsthand the difference between pull systems and the more traditional push system. Participants also learn to identify specific constraints (bottlenecks) on throughput for a given manufacturing process.

*Competencies Developed in This Module:*

- Describe and compare push and pull production control systems.
- Apply techniques used in pull production control systems.
- Design and operate a kanban system.
- Identify specific constraints (bottlenecks) on throughput for a given manufacturing process.
- Propose and evaluate a plan to improve cost, quality, and cycle time in a manufacturing process.

**Prerequisite:** Introduction to Just-in-Time (JIT) (PIC06)

Equipment Selection (PIC11) [12 EHI]

Participants learn skills that help them work with manufacturing teams that specify equipment required to produce quality products at required production rates.

*Competencies Developed in This Module:*

- Find, organize, and manage equipment information.
- Identify and analyze tangible strengths and weaknesses of equipment designed for similar processes.
- Identify intangible factors to consider when selecting equipment.
- Estimate the total costs for equipment during its useful life: purchase prices, installation, taxes, spare parts, expected maintenance costs, power and utilities, training, consumable tooling.
- Make a selection decision that considers multiple alternatives, tangible and intangible cost elements, implementation and operating conditions.
- Present equipment selection proposals to different audiences.

**Prerequisites:** Plastics Manufacturing Processes and Materials (MPM06), Tooling for Manufacturing (MPM08), Manufacturing Work Cell Design (PIC12)

Manufacturing Work Cell Design (PIC12) [8 EHI]

This module focuses on the design and implementation of work cells to accomplish lean production operations that balance machine processes, part handling between stations, and the actions of operators in a smooth, efficient, ergonomically safe manner.

*Competencies Developed in This Module:*

- Present and discuss the significance of key terms and concepts related to work cell design and operation.
- Create an effective work cell design using a structured methodology.
- Construct and operate a work cell given a set of conditions including customer demand, operation time details, production volumes, and enterprise constraints.
- Compare the theoretical design output of a production cell to its actual output.
- Develop project plans for work cell implementation and operator training.
- Perform an analysis of a business application of cellular manufacturing.

**Prerequisites:** Process Flow and Lead Time Reduction (PIC07), Consistent Work Methods and Build to Demand (PIC08), Kanban and Pull Systems (PIC10), Introduction to Just-in-Time (PIC06)

Manufacturing Facilities Design (PIC15) [10 EHI]

This module engages participants in ALTs that demonstrate modern facility layout methods that promote one-piece flow and lean production. Additional skills are developed in the selection of appropriate material handling equipment for manufacturing operations.

*Competencies Developed in This Module:*

- Describe the objectives and principles of manufacturing facility design with an emphasis on one-piece flow and lean manufacturing operations.
- Describe the tools used to design and specify appropriate material handling systems.

**Prerequisites:** Equipment Selection (PIC11), Manufacturing Work Cell Design (PIC12), Advanced Machining (MPM09), Teamwork (HCT06)

## Quality Management Cluster (QUA)

The manufacturing engineering technician will work with the quality professionals in the enterprise to help meet customer expectations and achieve customer loyalty. Particular emphasis is on process control, process improvement, and precision measurement.

### Modules

Quality Foundations (QUA01) [16 EHI]

By taking part in the simulation of real life situations, participants get hands-on experience with quality-management techniques that improve the whole system of manufacturing. Participants interpret customer needs, evaluate customer service, create control charts, and identify barriers to change.

*Competencies Developed in This Module:*

- Apply quality principles to individual and organizational improvement.
- Interpret the impact of quality on the supply chain.
- Interpret the needs of internal and external customers.
- Monitor and evaluate customer service to provide ongoing customer satisfaction.
- Apply the concepts of statistical variation and common cause versus special cause.
- Create simple control charts.
- Apply the Theory of Knowledge to the Plan-Do-Study-Act cycle.
- Identify barriers to change and change enhancers within an organization.
- Use some tools of world class quality (force field analysis, control charts, system diagrams, and process documentation) to develop approaches to solving problems.

**Prerequisites:** Teamwork (HCT06), Basic Statistical Variation (MAF13)

Process Control (QUA02) [10 EHI]

This module concentrates on the practical applications of statistical analysis in manufacturing. Participants get hands-on experience through

a series of exercises demonstrating process control principles, SPC tools, process capability analysis, and the pursuit of continuous improvement.

*Competencies Developed in This Module:*

- Apply the concepts of forms of variability and process dominance to the selection of an appropriate control technique.
- Acquire, analyze, and interpret data from a process to determine if that process is in statistical control and capable of meeting customers requirements.
- Apply problem-solving techniques to the development of an improvement plan for processes that are not in statistical control and/or not capable of meeting customer requirements.

**Prerequisites:** Statistical Distributions (MAA07), Quality Foundations (QUA01), Teamwork (HCT06)

Continuous Process Improvement (QUA03) [20 EHI]

Participants develop skills in applying many tools for problem solving in manufacturing enterprises to improve production processes.

*Competencies Developed in This Module:*

- Use flow charts and diagrams to analyze and solve quality problems.
- Identify and establish system and/or financial measures for throughput improvement, quality improvement, and waste reduction.
- Choose and apply the appropriate problem solving model and tools to improve throughput.
- Choose and apply the appropriate problem solving model and tools to reduce waste.
- Choose and apply the appropriate problem solving model and tools to improve quality.

**Prerequisites:** Performance Measures (EIN05), Process Control (QUA02), Statistical Experiments (MAA09), Process Flow and Lead Time Reduction (PIC07)

Measurement and Calibration (QUA04) [16 EHI]

Participants develop an appreciation for the need for precision and for the tools and techniques used to verify product quality using the principles of dimensional metrology.

*Competencies Developed in This Module:*

- Demonstrate the proper use of conventional measuring tools and precision instruments for measuring length, roundness, surface finish, flatness, diameter, and contour of physical parts.
- Use proper techniques of metrology to ensure that products meet specifications.
- Properly apply hand instruments (0.015 in to 0.001 in.), comparison measures (0.0001 in. to 0.00001 in.), electronic and pneumatic gaging, sensor measurements, and coordinate measurements for specified products.
- Discuss calibration systems and properly apply appropriate systems to the calibration of instruments to be used in a specified manufacturing operation.

**Prerequisites:** Precision, Accuracy and Tolerance (MAA04), College Geometry (MAA01), Continuous Process Improvement (QUA03)

## Manufacturing Processes and Materials Cluster (MPM)

Manufacturing engineering technicians must understand the systems concept of manufacturing that integrates a design, an engineering material, and a manufacturing process into a produced product. They will plan, organize, implement, and manage the transformation of raw stock in accordance with product design specifications. A knowledge of the structure and properties of engineering materials, both metallic and non-metallic, is essential to performing these tasks. Emphasis in this cluster is directed toward the application of manufacturing skills and knowledge in the solving of industrial production problems and the efficient operation of production systems. The integration of people, machines, and state-of-the-art manufacturing processes to add value to a raw material in a production setting is the hallmark for the manufacturing engineering technician.

**Curriculum note:** The specific manufacturing processes to be included in any given manufacturing engineering technology program are left to the local institution, considering the needs of the employers of graduates of that institution. This report specifies the list of recommended modules for a technician who will work primarily in industries that process metallic and nonmetallic materials into mechanical and structural components. The first seven modules listed are the recommended core for any associate degree program in manufacturing engineering technology. The final two may be replaced by modules that meet local needs. Examples may include composite materials and manufacturing processes, manufacturing processes for electronic

systems, assembly processes and systems, or wood materials and manufacturing processes.

**Safety note:** All modules in this cluster require as prerequisite knowledge the principles included in the foundation module, Introduction to Safety and Environmental Precautions (SCF02) listed in Appendix A as a foundation module for the Science Cluster. It is expected that all participants will have developed these basic competencies from their secondary school experiences. Otherwise, instruction as outlined in SCF02 should be completed to ensure that participants follow safe practices.

In addition, each module includes safety and disposal information appropriate to the activities of each ALT and each transfer activity.

## Modules

Principles of Manufacturing Processes (MPM01) [15 EHI]

Participants explore and analyze the way products are made, relate their observations to an established taxonomy of manufacturing processes, and discover resources available through professional engineering societies. This module helps participants recognize the need for ongoing professional development in their careers.

### *Competencies Developed in This Module:*

- Explain the relationship between process, design, and material in manufacturing.
- Use the Taxonomy of Manufacturing Processes to locate and describe manufacturing processes.
- Analyze product features to identify manufacturing processes that may have been used.
- Describe examples of how different manufacturing processes can be used to produce the same product.
- Suggest manufacturing processes required to make a product design from an engineering drawing and explain why the recommended suggestions were made.

Basic Material Removal (MPM02) [20 EHI]

Basic Material Removal introduces participants to five basic machine tools used for material removal: lathes, drill presses, saws, milling machines, and grinders. Participants develop knowledge and practical skills through demonstrations, discussions, and hands-on machining.

*Competencies Developed in This Module:*

- Describe the role of the Taxonomy of Manufacturing Processes, including its effect on product development.
- Demonstrate safe operating procedures for each machine tool used.
- Research and discuss theoretical and background information about milling machines, drill presses, horizontal and vertical band saws, lathes, and grinders.
- Develop a list of material-cutting operations and identify the sequence needed to make a specific product.
- Use hand tools to support the setup and operation of material-cutting machinery.
- Operate lathes, drill presses, milling machines, and horizontal and vertical band saws at an introductory level.
- Select cutting speeds and feeds and calculate the RPM appropriate to a specific material/cutting tool combination.
- Link the basic theory of material cutting to tool geometry (chip formation).
- Apply basic precision measurement instruments before, during, and after material removal operations to ensure that product specifications and tolerances are met.
- Describe the relative motions of the machine and describe the interactions of various subsystems, including the machine tool, machine controls, drive mechanisms, cutting tools, tool holder, workpiece, and work holder.

**Prerequisite:** Principles of Manufacturing Processes (MPM01)

Metallic Materials (MPM03) [15 EHI]

Metallic Materials helps participants develop a basic understanding of the structures and properties of common metallic materials. Participants also learn how those properties relate to product design and manufacturing processes.

*Competencies Developed in This Module:*

- Describe how the structures and properties of selected metallic materials are related to performance in terms of strength, stiffness, ductility, impact resistance (toughness), wear qualities (hardness), and density.
- Use appropriate reference materials—such as *American Society for Testing and Materials Standards*, mill product literature, and the *ASM Metals Handbook*—to locate specific metallic materials by

number and identify ways in which raw metallic materials can be made and used.

- Predict how the mechanical properties of metallic materials will change as a result of use environments.
- Relate the mechanical properties of metallic materials to their potential manufacturability.
- Select appropriate metallic materials to meet customer requirements for a particular product, including process, manufacturability, availability, cost, weight, mechanical properties, and use environment.

**Prerequisites:** Principles of Manufacturing Processes (MPM01), Properties of Solids (SCF07), Atomic Structure and the Periodic Table (SCF09)

Metal Forming and Joining (MPM04) [15 EHI]

In Metal Forming and Joining, participants learn to identify the processes used to make a given product and then produce metal parts and products using these processes. Participants operate a basic sheet metal forming machine, operate at least one basic welding machine, and produce at least one green sand casting.

*Competencies Developed in This Module:*

- Describe each of the following processes—welding, casting, forming, and forging—including workpiece materials, consumable materials, safety procedures, necessary equipment, and manufacturing applications.
- Differentiate between various processes within the categories of welding, casting, forming and forging, and identify which process would be most applicable and cost-effective for a given product.
- Locate and interpret manufacturing process data (including materials, machines, and process parameters) in reference manuals.
- Using safe and proper procedures, operate basic sheet metal forming machines such as a box and pan brake, shear, and piercing and blanking machines.
- Using safe and proper procedures, operate at least one basic welding machine such as gas metal arc welding, gas tungsten arc welding, shielded metal arc welding, or oxygen acetylene cutting.
- Using safe and proper procedures, produce at least one green sand casting.

**Prerequisites:** Metallic Materials (MPM03)

## Non-Metallic Materials

(MPM06) [15 EHI]

Participants investigate a diverse range of non-metallic materials (such as composites, ceramics, abrasives, elastomers, wood, paper, food) and the properties unique to each one, as well as selection criteria, cost considerations, and processing techniques.

### *Competencies Developed in This Module:*

- Define and provide examples of each of the following materials: wood and paper, ceramics, abrasives, food, elastomers, and composites.
- Explain the following concepts as they relate to the appropriate non-metallic material: directionality, fatigue, strength-to-weight ratio, ductile-brittle transition, impact resistance, temperature resistance, moisture resistance, thermosetting plastics, thermoplastics, resiliency, elongation, thermal conductivity, and electrical conductivity.
- Identify the properties that must be considered when selecting a non-metallic material.
- Recognize if/how temperature affects these properties.
- Describe the processing techniques available for wood and paper, ceramics, abrasives, food, elastomers, and composites.

### **Prerequisites:** Metallic Materials (MPM03)

## Plastics Manufacturing Processes and Materials (MPM07) [15 EHI]

Plastics Manufacturing Processes and Materials introduces participants to the properties of plastics materials and the primary manufacturing processes used with plastics: extrusion, injection molding, blow molding, rotational molding, and thermoforming.

### *Competencies Developed in This Module:*

- Define terms related to plastics and plastics processes.
- Explain each of the following processes: injection molding, extrusion, blow molding, rotational molding, and thermoforming.
- Identify process selection considerations and limitations, including design, volume, dimensions, tolerances, and cost.
- Describe the physical method of processing and the machinery and tooling used for each of the following processes: injection molding, extrusion, blow molding, rotational molding, and thermoforming.
- Identify process variables (including time, temperature, and pressure) which may affect product quality and how these variables affect the mechanical properties of materials during processing.

- Identify the process used to make a plastics product.
- Use reference materials (such as Material Safety Data Sheets and Modern Plastics Encyclopedia) to locate relevant information about plastics processes and materials.
- Make a plastics product using one or more of the following processes: injection molding, extrusion, blow molding, rotational molding, or thermoforming.
- Identify alternative processes that could be used and situations in which these alternatives apply.

**Prerequisite:** Principles of Manufacturing Processes (MPM01)

Tooling for Manufacturing (MPM08) [15 EHI]

Tooling for Manufacturing introduces participants to basic locating and clamping techniques, the use of fixed-limit and functional gages, and modular tooling techniques. In addition, participants select tooling materials to meet production criteria and analyze economic data to select the most cost-effective tool design.

*Competencies Developed in This Module:*

- Design a fixture for a given product using clamping principles and locating principles.
- Identify types of fixed-limit gages, explain the application of fixed-limit and functional gages, and design both fixed-limit and functional gages.
- Use modular tooling techniques to select components, design layout, and assemble a tool for a given product.
- Select tooling materials to meet production criteria.
- Identify basic types of dies and discuss their applications in metal forming operations.
- Identify basic jigs and fixtures and explain their functions.
- Analyze economic data (including material, production rate, design, product life, design flexibility, environmental factors, and changeover of fixtures) to select the most cost-effective tool design.

**Prerequisites:** Right Triangles and Trigonometric Functions (MAF11), Geometric Dimensioning and Tolerancing (PRP08), Computer Aided Design (PRP03), Basic Material Removal (MPM02), Metallic Materials (MPM03)

Heat Treatment/Thermal Processes (MPM05) [15 EHI]

Participants learn the principles and practices of heat treatment of metallic materials to produce desirable properties of strength, hardness, wear resistance, ductility, and impact resistance.

*Competencies Developed in This Module:*

- Describe the basic principles of heat treatment and their influence on the mechanical properties of metals including strength, hardness, ductility, toughness, and wear resistance.
- Analyze several selected engineering materials to highlight advantages and limitations that might limit the selection of each for use with a given manufacturing process.
- Perform basic heat treating operations to include hardening, tempering, and annealing.
- Discuss the importance of the time-temperature-transformation (TTT) curve in producing a particular microstructure.
- Perform the surface hardening process of carburizing to produce a hard skin around the core of a ferrous part.
- Discuss the application of stress relieving and normalizing to reduce or eliminate stresses during subsequent manufacturing processes.
- Describe the importance of carbon to the heat treatment of steel to include the range from low carbon to high carbon content.

**Prerequisites:** Metallic Materials (MPM03)

Advanced Machining (MPM09) [15 EHI]

Building on the competencies developed in the study of basic material removal processes, participants gain additional skills in more complex machining processes used to produce a wide variety of parts.

*Competencies Developed in This Module:*

- Describe and discuss the basic types of cutting tools, their materials, and their geometries as used for turning and milling operations.
- Describe and discuss the basic process of chip formation during turning and milling operations and discuss the relationships between chip form and the geometry of the cutting tool.
- Explain the relationships among machining variables such as workpiece material, material removal rate, and cutting tool geometry on the expected surface finish of the workpiece, tool wear, cutting forces, and power required to drive the machine.
- Demonstrate the ability to perform accurate thread cutting on a lathe.

- Demonstrate the ability to perform accurate milling on multiple surfaces of a prismatic part.
- Demonstrate the ability to perform surface grinding of plane surfaces to produce dimensional accuracy to at least  $\pm 0.0001$  in.
- Complete the production of a product having at least three parts that must fit together and operate reliably. Tolerances on dimensions of mating features are to be no more than  $\pm 0.002$  in. The look, feel, fit, and finish of the completed product must be at a quality level expected of commercial products or better.

**Prerequisites:** Basic Material Removal (MPM02), Metallic Materials (MPM03)

## Manufacturing Systems and Automation Cluster (SYS)

Manufacturing engineering technicians will plan, design, implement, use, and troubleshoot manufacturing systems and controls to monitor production quantities, costs, and quality; integrate controls into automated production systems; and integrate manufacturing operations with enterprise management systems.

### Modules

Electrical and Electronic Controls (SYS01) [15 EHI]

Electrical and Electronic Controls prepares participants to select and use various electrical and electronic power and control devices appropriate for an industrial application. Participants apply troubleshooting techniques in electrical and electronic controls and power circuits.

*Competencies Developed in This Module:*

- Locate and explain the specifications for and ratings of electrical components and control equipment.
- Select the most appropriate control device for a given operation.
- Apply troubleshooting techniques to control circuits, digital circuits, and the following control devices typically found in industrial applications: fuses, circuit breakers, disconnects, and switching hardware.
- Interpret standard wiring diagrams and schematic diagrams for use in troubleshooting control circuits.
- Utilize the following electromechanical control devices in practical applications of DC and AC motor control: limit switches, relays, solenoids, motor starters, and contactors (electromagnetic and electronic).

- Demonstrate an understanding of grounding considerations for power and control circuits.
- Demonstrate an understanding of electrical and pneumatic controls for manufacturing equipment.
- Interpret information in various catalogs pertaining to electrical and electronic components and devices.

**Prerequisites:** Vector Analysis (MAA02), Further Applications of Trigonometry (MAA03), Precision, Accuracy, and Tolerance (MAA04), Differentiation (MAA11), Integration (MAA13), Fundamentals of Electronics (SCA07)

Data Acquisition and Analysis (SYS02) [15 EHI]

Participants engage in several activities in which they use systems for acquiring data about production quantities and product quality. These data are analyzed and integrated with information systems that support the manufacturing enterprise.

*Competencies Developed in This Module:*

- Describe manual and computer assisted methods of acquiring, analyzing, transmitting, and using data from manufacturing operations for the management of those operations and the integration of the operations with enterprise management systems.
- Describe the basic nature of the following techniques and indicate how they can be used in a manufacturing operation: computer data acquisition, analog to digital conversion, radio frequency data transmitters, bar coding, cell controllers, telecommunications, electronic data interchange with suppliers and customers, document storage and retrieval systems, and online quality management systems.

**Prerequisite:** Fundamentals of Electronics (SCA07)

Fluid Power (SYS03) [15 EHI]

Participants learn the fundamentals of pneumatic and hydraulic fluid power components and systems as they are applied in automated production operations.

*Competencies Developed in This Module:*

- Describe and calculate how the pressure and flow of a fluid relates to the functioning of a hydraulic actuator.
- Demonstrate an understanding of forces, pressures, power, energy conversion, efficiencies of components, and energy losses due to

friction, slippage, and leakage, including the effect of energy storage on efficiency and size of power units (energy converters).

- Predict the performance of an actuator under meter-in, meter-out conditions and bleed-off circuits.
- Read and interpret hydraulic and pneumatic schematics and model codes.
- Specify an o-ring size, material, and oil capability for a specific application.
- Specify a hydraulic power unit (HPU) considering pressure, flow (power), heat, dissipation, filtration, fluid, and maintenance.
- Demonstrate an understanding of proportional controls related to fluid power, and decide when and why to use electromechanical, pneumatic, and hydraulic actuation.
- Discuss safety and environmental concerns related to fluid power such as leakage, noise, reclaiming, and disposal.
- Demonstrate an understanding of the fundamental principles of pneumatics, hydraulics, and vacuum technology.
- Demonstrate an understanding of cost issues when selecting hydraulic, pneumatic, and vacuum components.

**Prerequisite:** Units and Conversions (MAF01), Product Development and Testing (PRP04), Robots and Programmable Logic Controllers (SYS05), Electrical and Electronic Controls (SYS01)

Computer Numerical Control (SYS04) [15 EHI]

Through Computer Numerical Control (CNC) machinery operation and programming tasks, this module introduces participants to the capabilities of CNC turning centers and machining centers. Participants plan and implement the automatic production of parts using CNC machine tools.

*Competencies Developed in This Module:*

- Plan and implement the automatic production of parts using computer numerical control (CNC) machine tools.
- Understand the capabilities of CNC turning centers and machining centers.

**Prerequisites:** Precision, Accuracy and Tolerance (MAA04), Basic Material Removal (MPM02)

Robots and Programmable Logic Controllers (SYS05) [15 EHI]

In Robots and Programmable Logic Controllers, participants apply fundamental math and science skills to the implementation of robot actions and PLC controls typically required in automated production systems.

*Competencies Developed in This Module:*

- Describe the development of robots in the past four decades, as well as recent advances in robotics technology.
- Describe the role of robotics in industrial automation and identify its major applications in manufacturing.
- Explain differences and similarities among various types of industrial robots based on two major classification schemes.
- Define robotics terminology, identify the major components of a robot system, and explain their role in the robot's operation cycle.
- Identify home position, fixed and floating zero with absolute and incremental dimensioning, and apply the concepts of accuracy and resolution.
- Plan and implement a material handling task in a work cell using a robot.
- Demonstrate the ability to program robotic systems as applied to manufacturing operations and plan for their implementation in appropriate processes.
- Identify major components/subsystems of a typical PLC, explain terminology associated with PLC technology, and comprehend the contents of PLC manuals and documentation.
- Explain the role of PLCs in industrial automation, including the role of a PLC in a robotic work cell.
- Identify input/output devices commonly used in a PLC application and explain hardware interfacing considerations in a PLC application.
- Explain the differences, advantages, and disadvantages of relay approach and PLC logic approach, and explain ladder diagramming.
- Explain the program download and upload process for a PLC application, and develop, download, execute, and troubleshoot a ladder logic program.
- Plan and implement an automated manufacturing cycle using a programmable logic controller (PLC).
- Demonstrate the ability to program and troubleshoot PLCs to control manufacturing systems.

**Prerequisite:** Fundamentals of Electronics (SCA07)

## Enterprise Integration Cluster (EIN)

Manufacturing engineering technicians are key players in a manufacturing enterprise because they must integrate the operations of many functions of the enterprise and interface with people in many parts of the enterprise. Their work takes data and information from product designers, vendors, customers, sales and marketing staffs, and enterprise managers. The result of their work is a set of products or services delivered to customers and the data that are used to manage the enterprise. Therefore, technicians should have knowledge of the enterprise management process so they can contribute effectively to the efficient management of the enterprise.

### Modules

Supply Chain Management (EIN01) [10 EHI]

Participants learn the fundamentals of purchasing and effective methods of interacting with vendors of materials and components to ensure smooth and efficient production operations.

#### *Competencies Developed in This Module:*

- Formulate desirable vendor attributes.
- Describe how vendor certification relates to JIT and TQM in manufacturing operations.
- List the steps needed for vendor certification.
- Describe effective methods of data collection and analysis of vendor performance.
- Describe the purchasing function.
- Describe the legal relationships between vendors and the manufacturing enterprise.

**Prerequisites:** Quality Foundations (QUA01), Principles of Production and Inventory Control (PIC01), Conceptual Design (PRP02)

Manufacturing Information Systems (EIN02) [15 EHI]

Participants learn basic principles of effective manufacturing information systems that provide timely, accurate, and properly formatted information for management of a manufacturing enterprise. Emphasizes those aspects of the system that affect manufacturing operations and with which the manufacturing engineering technician has significant involvement.

*Competencies Developed in This Module:*

- Explain how information systems are used for the management of production operations and the business processes of the enterprise.
- Describe the importance of integrating the operations of the enterprise through effective interpersonal and data communications.
- Plan and implement data management systems for production operations.
- Describe telecommunication systems that can be used to communicate among the functional units and physical facilities of the enterprise.

**Prerequisites:** Electrical and Electronic Controls (SYS01), Data Acquisition and Analysis (SYS02), Computer Numerical Control (SYS04), Optics (SCA04), Computer Aided Design (PRP03), Computer Skills (HCT02)

Customer Satisfaction (EIN03) [10 EHI]

Customer Satisfaction introduces participants to the concepts of marketing and the relationship between marketing and customer satisfaction. Participants apply the elements of the marketing mix, the promotional mix, and pricing strategy to a product or service.

*Competencies Developed in This Module:*

- Apply the elements of the marketing mix to a product or service.
- Apply the elements of the promotional mix to a product or service.
- Apply the elements of pricing strategy to a product or service.
- Apply a consumer research technique to identify elements of customer satisfaction.

**Prerequisite:** Teamwork (HCT06)

Financial Management (EIN04) [10 EHI]

This module provides participants with the ability to use basic accounting data to understand the financial health of a manufacturing enterprise and to contribute to the improvement of financial performance.

*Competencies Developed in This Module:*

- Interpret basic accounting data and reports.
- Provide input to and use the results of activity based accounting systems.

Performance Measures (EIN05) [15 EHI]

Performance Measures gives participants a working knowledge of the terms, concepts, and principles typically used by manufacturing industries to measure the performance of a given enterprise. Participants become familiar with basic financial statements, product costing, product/process improvement relating to costs, and cost centers.

*Competencies Developed in This Module:*

- List and evaluate all sources of revenue in a manufacturing enterprise.
- List and evaluate all sources of expense in a manufacturing enterprise.
- Determine the owners' equity in an organization by using the accounting equation  $A - L = E$ .
- Construct and explain a basic cost analysis for a given product.
- Interpret the impact of planned and unplanned changes in product cost.
- Justify a planned capital acquisition to reduce product or process cost.
- Examine and interpret a simple manufacturing cost center budget.

**Prerequisites:** Principles of Manufacturing Processes (MPM01), Financial Management (EIN04)

Capstone Project (MFG02) (60 EHI)

After gaining the expected set of competencies defined in the curriculum, each participant will complete a project having the following characteristics:

1. The project should be highly focused and should involve an actual industry need.
2. Participation on a team should be a normal part of the project, with team members being fellow participants or co-workers in a cooperating industry.
3. The project should be sufficiently complex to require the participant to demonstrate competence in the application of a large set of competencies developed in the program.
4. The project could be done in cooperation with the participant's employer if he or she were employed full time or part time or working on a cooperative education or internship plan.

5. The project could be completed within a model factory or other manufacturing teaching facility in an educational institution.
6. Special emphasis should be placed on the incorporation of modern manufacturing processes, quality management principles and practices, and production philosophies into product and process designs.
7. Completing the project should demonstrate effective manufacturing facility design, the application of appropriate material handling systems, and appropriate use of automation and production operations, with an emphasis on one-piece flow and lean manufacturing operations.
8. The project should require the integration of the product and process design with enterprise management needs such as financial justification, cost estimating, manufacturing cost analysis, customer order processing, information management, materials management, strategic planning, and overall business practices.

## 8.0 Curriculum Outline by Typical Path Through the Program

Flexibility for the participants is one of the primary goals of the proposed modular curriculum in manufacturing engineering technology. In an ideal situation, a participant could undertake at any time any module for which she or he has the proper prerequisite knowledge and skill.

The program need not be tied to traditional terms (quarters or semesters) currently used by most colleges and universities for scheduling classes. The duration of any module should be significantly less than that required for traditional courses based on the number of class hours per week for a given number of weeks in a term. The pace of any module should be set by the participants and the facilitator to match the availability of proper facilities and the actual time required for participants to complete the authentic learning tasks and the transfer activity. Because each activity in each module is designed to be a team-based experience, it will also be necessary that a critical number of participants be available.

The situation described above makes it impossible to set down a particular path that a given participant would follow to complete the program. Rather, the path should be planned by the participant and an advisor using a scheduling tool such as Microsoft® Project or some other project planning software. The path will take on the nature of a critical path, as employed to plan complex projects that use a variety of resources and for which there are numerous interdependencies among project elements.

### 8.1 An Illustration of a Participant's Path Through the Program

This section presents an example of how a participant might proceed through the entire program. The illustration rests on the following assumptions:

- The curriculum is that described in Section 7.0 of this report, containing 67 modules and six traditional courses of three quarter credits each.
- The normal size for a module is 10 equivalent hours of instruction (EHI). A module of this size can be completed in approximately four weeks. This is based on the observation that, in an average module, the participant develops approximately the competencies that would be covered in a one credit course in one quarter. Because the modules are not limited to traditional scheduling, the actual time

to complete an average module could be more or less than three weeks.

- The modules in fact have different sizes, ranging from eight to 30 EHI. The estimated time in weeks for completion was determined by applying the factor of 0.4 times the number of EHI. Therefore, the range of estimated time for completing a module is from 3.2 to 12 weeks.
- The Capstone module (MFG02) is planned to be a very comprehensive project taken at the end of the program. The participant is expected to draw on all prior learning to complete a real, complex project. It is rated at 60 EHI and would, therefore, require approximately 24 weeks to complete if it were taken along with other program requirements. Alternatively, the Capstone module could be taken by itself with more intensive effort and completed in a shorter calendar time.
- The first modules completed by the participant are Introduction to World Class Manufacturing (MFG01), Principles of Manufacturing Processes (MPM01), and Professional Development (HCT11).
- When a participant is prepared to take a variety of modules at any given time, a preferred sequence is consulted to recommend a particular set of modules.
- The participant is a fulltime student who can work on several modules during the same time period.
- The participant has the appropriate preparation from high school or equivalent experience to satisfy the recommended twelfth grade standards in mathematics, science, communications, and computer skills.
- The participant pursues the associate degree virtually year round.
- The necessary facilitator, facilities, and a sufficient number of fellow participants are available whenever a given participant desires to take a module.

The example path is shown on the inserted oversize page (inside the back cover). It was prepared using Microsoft® Project, a popular project planning software product. Each of the 67 modules and six courses was entered along with its prerequisites and its number of EHI (refer to Appendix B). A secondary control, called the sequence (SEQ), was entered to indicate the approximate place in which each particular module should be taken. The duration in weeks was computed as described above.

The graphic output illustrates the nominal order in which a participant could take the modules. This kind of chart is often called a PERT chart, a name derived from its full title, Program Evaluation and Review Technique. It is a system of planning, scheduling, controlling, and

reviewing a series of interdependent events in order to follow a proper sequence and complete a project as quickly and inexpensively as possible.

The time scale is shown in months, with three months to a quarter. The chart shows that the student should be able to complete the program in six quarters, a total time equivalent to that for a traditional associate degree program.

Note that at the beginning of most quarters, there are several modules listed that can be taken at a given time. The participant would work with an advisor to plan for the sequencing of those modules, because the student could actually complete up to three modules sequentially in a given quarter. Thus, it is judged that the total time allocated to the completion of the entire program is reasonable for an associate degree program.



## 9.0 Implementation Status and Future Directions

At the time of writing this report, the National Center of Excellence for Advanced Manufacturing Education (NCE/AME) has been operating for almost five years, starting on January 1, 1995. During the first three years, NCE/AME staff devoted a significant amount of effort to developing the modular architecture, the pedagogy, the assessment methodology, and the curriculum outline. Staff spent additional time evolving a process for developing modules that had a uniform look and feel and that faithfully implemented the module architecture.

The module development process evolved over a period of approximately two years, during which several modules were drafted and tested. During this time, staff designed a module format and recruited content experts to write the modules. NCE/AME provided a relatively small amount of staff support to advise the writers. While the writers were skilled in the subject matter, there was a general lack of adherence to the desired format. These early attempts did not produce the desired quality and consistency.

During the last part of the third year of the project, the module development process was revised to place more of the responsibility for writing on professional instructional design staff members within the NCE/AME. Staff recruited additional module development teams from a national base of educators and industry professionals. In the new process, the teams meet with an instructional design staff person, called a Coordinator, who guides the work of the team members. The process consists of the following functions:

1. The team refines and expands to a higher level of specificity the list of module competencies to be developed by the participants.
2. The team creates activities that provide the participants experiences in which they develop the desired competencies. These are the authentic learning tasks (ALTs).
3. The team members draft the initial descriptions of the ALTs and a transfer activity and submit them to the Coordinator.
4. The Coordinator edits the initial drafts, writes introductory and bridging material, and formulates the text into the standard format.
5. The team members review the new draft and develop a set of authentic assessment techniques based on the deliverables from the ALTs.

6. The Coordinator creates scoring rubrics as evaluation tools. The rubrics enable facilitators of the module to judge whether each participant has demonstrated each of the stated competencies at a desired level.
7. After several iterations and after reviews by internal staff and external industry reviewers, the module is printed in an alpha version.
8. A variety of facilitators, both local and national, test the alpha version in real classroom situations. The objective of this testing is to confirm that the module activities can be completed successfully.
9. The Coordinator uses comments from the alpha testing to revise and improve the module, and a beta version is printed.
10. Another group of facilitators tests the beta version to determine the level of competency demonstrated by the participants. Additional recommendations for improvement are requested from the facilitators.
11. The Coordinator makes final revisions to the module and it is printed. It is then considered to be finished and available for adoption by educators nationally.

This process is very time and labor intensive. For this reason, it is planned that 28 modules from the associate degree curriculum will be completed by the end of the sixth year of operation of the NCE/AME (the end of the year 2000).

Therefore, there is a need to continue the module development process to complete the remaining 39 modules, giving the total 67 modules required for the associate degree. NCE/AME is requesting additional funding to continue this work. If the funding is granted, all modules should be completed by the end of the year 2003.

## 9.1 Future Directions in Academia

In addition to production of the modules for the associate degree curriculum, staff efforts are being directed toward assisting other colleges in the implementation of the activity-based, modular approach to instruction. In some cases, the assistance aids the college staff in introducing the available modules into traditional courses. This is considered to be a logical step because the organizational structure of most colleges does not permit the move to a fully modular curriculum. The experience gained from using the modules helps instructional staff members move toward activity-based techniques. Of course, there is not yet available a total set of modules for a complete associate degree program.

Some of these implementation projects are within manufacturing engineering technology programs, either those already in existence or those just being implemented. But the module development process is seen as desirable in many other academic disciplines. Some of the implementation projects have served a broader clientele than just the manufacturing engineering technology program.

The services of the NCE/AME staff in assisting other colleges adopt the activity-based, modular approach to instruction are provided on a fee-for-service basis. However, there is a need to upgrade the materials used for this service and to engage in broader efforts to market these services. NCE/AME is seeking additional funding to develop the necessary tools to disseminate the results of the project effectively nationwide.

## 9.1 Future Directions in Industrial Training

Early results have shown the modular architecture developed by the NCE/AME to be attractive to industries as they create learning experiences for their own employees and their customers. Some projects have been very successful in adapting the module development process to the special needs of an industry client.

One module in particular was developed in cooperation with an industrial association in the Dayton, Ohio region. Called *Tools for the Future*, this module uses the principles espoused in the books *The Seven Habits of Highly Effective People*, by Stephen Covey, and *The Goal*, by Eliyahu M. Goldratt, to guide teams of people from a given company through activities that develop their ability to perform effective team-based problem solving. The results have demonstrated increased communication among associates at all levels in the companies, more rapid and successful problem solving, and a greater ability to satisfy customer needs.

The NCE/AME plans to expand this service to a broad array of industry clients on a fee-for-service basis. This is considered to be complementary to the mission of the NCE/AME and to the Advanced Integrated Manufacturing Center (AIM Center) of which it is a part. The AIM Center provides many kinds of assistance to industries to upgrade their employees and to assist in the implementation of new technologies and modern lean production processes.



# Appendix A: Entry Requirements in Mathematics and Science

## Mathematics Foundation Modules (MAF)

The foundation modules listed here constitute the principles of mathematics that participants are expected to have developed from secondary school prior to entry into the manufacturing engineering technology program. The concepts included are those typically found in courses called Algebra I, Algebra II, Geometry, and Trigonometry. Some schools use different names.

This list can be used to gage the readiness of a particular prospective participant. It can also be used to develop modules for review and study by those who have not developed competencies equivalent to the national twelfth grade standards.

**Reference:** National Council of Teachers of Mathematics, *Curriculum Standards for School Mathematics*, Reston, Virginia, March, 1989.

## Modules

### Units and Conversions (MAF01) [10 EHI]

This module provides participants with an understanding of units and conversions, including: methods for calculating conversion factors with nonstandard units, conversions of specifications between the US and metric systems, advantages of using the metric system, and problem solving through dimensional analysis.

#### *Competencies Developed in This Module:*

- Describe and define the primary units of measurement in the United States Customary System (US).
- Describe and define the primary units of measurement in the International Metric System (SI).
- Use both the US and the SI measurement systems in real world problems and everyday situations as applied to length, area, dry volume, liquid volume, temperature, mass, weight, force, and energy efficiency.
- Perform unit conversions between the US and SI systems and within the US and SI systems.
- Use dimensional analysis to ensure that quantities are reported in appropriate units.

Equations and Formulas (MAF02) [15 EHI]

*Competencies Developed in This Module:*

- Move beyond concrete numerical operations to use abstract concepts and symbols in solving problems.
- Solve linear equations and algebraically manipulate formulas.
- Extract the mathematical content and relationships, especially proportional relationships, present in real world problems and everyday situations.
- Establish ratios with and without common units to solve problems.

**Prerequisite:** Units and Conversions (MAF01)

Linear Functions (MAF03) [15 EHI]

*Competencies Developed in This Module:*

- Graph linear functions.
- Find slope and intercept points.
- Interpret slope, ordered pairs, and graphs.
- Develop graphical techniques of solution for problem situations involving functions.
- Perform curve fitting to predict data values.
- Find the equation of a straight line.
- Solve inequalities and graph inequalities on the number line.

**Prerequisite:** Equations and Formulas (MAF02)

Quadratic Functions (MAF04) [12 EHI]

*Competencies Developed in This Module:*

- Solve quadratic equations by factoring, completing the square, square root method, and the quadratic formula.
- Solve applications of minima and maxima, and related rate problems.

**Prerequisite:** Linear Functions (MAF03)

Exponentials and Logarithms (MAF05) [15 EHI]

*Competencies Developed in This Module:*

- Define a logarithm and relate it to its exponential form.
- Graph logarithmic functions.
- Graph exponential functions.
- Solve exponential growth problems.
- Simplify expressions containing logarithms.

**Prerequisite:** Quadratic Functions (MAF04)

Functions (MAF06) [15 EHI]

*Competencies Developed in This Module:*

- Use multiple representations of functions to solve problems.
- Analyze functions and their behaviors, including exponential, quadratic, polynomial, and logarithmic functions.
- Develop graphical techniques of solution for problem situations involving functions.
- Make connections between the parameters in a function and the related behavior of the function.
- Create and recognize a variety of function patterns.

**Prerequisite:** Exponentials and Logarithms (MAF05)

Systems of Equations (MAF07) [10 EHI]

*Competencies Developed in This Module:*

- Define matrices and their algebraic properties.
- Solve systems of equations by graphical and algebraic methods and matrices.
- Graph inequalities in the plane.

**Prerequisite:** Linear Functions (MAF03)

Two Dimension Figures (MAF08) [10 EHI]

*Competencies Developed in This Module:*

- Represent problem situations with geometric models and apply properties of figures.
- Use basic properties of angles and triangles.
- Apply concepts of perimeter, area, and volume for basic shapes.

**Prerequisite:** Equations and Formulas (MAF02)

Three Dimension Figures (MAF09) [10 EHI]

*Competencies Developed in This Module:*

- Represent problem situations with geometric models and apply properties of figures.
- Apply concepts of surface area, volume, density, and weight for basic shapes.
- Perform compass and straightedge constructions of geometric shapes.

**Prerequisite:** Two Dimension Figures (MAF08)

Coordinate Geometry (MAF10) [15 EHI]

*Competencies Developed in This Module:*

- Find the distance between two points in a coordinate system.
- Make connections between geometric figures and algebraic descriptions.
- Find the equation of a circle, parabola, ellipse, and hyperbola. Be able to graph them.
- Learn to locate points in three-dimensional space in either rectangular or polar coordinates.
- Find polar coordinates of a point. Express an equation in polar form and be able to graph it.

**Prerequisite:** Quadratic Functions (MAF04)

Right Triangles and Trigonometric Functions (MAF11) [10 EHI]

*Competencies Developed in This Module:*

- Find trigonometric function values of an angle (degree or radian) by calculation.
- Solve right triangles using the trigonometric functions.
- Use trigonometric functions to solve various types of problems.
- Use basic properties of angles and triangles.

**Prerequisites:** Linear Functions (MAF03), Two Dimension Figures (MAF08)

The Periodic Nature of Trigonometry (MAF12) [10 EHI]

*Competencies Developed in This Module:*

- Use trigonometric functions to solve various types of problems.
- Explore the periodic real world phenomena using the sine and cosine functions.
- Explore the geometric basis for functions of trigonometry.
- Graph sine, cosine and tangent functions. Identify amplitude, period and phase shift.
- Make connections between the parameters in a function and the related behavior of the function.

**Prerequisite:** Right Triangles and Trigonometric Functions (MAF11)

Basic Statistical Variation (MAF13) [10 EHI]

*Competencies Developed in This Module:*

Participants develop data collection, analysis, and presentation skills; a working understanding of measures of central tendency, variability, and the normal curve; an increased comfort level with statistics; and an awareness of the usefulness of statistics to manufacturing.

- Collect, process, and display data so that usable information is represented.
- Prepare basic charts and graphs.
- Make inferences based on data analysis.
- Apply measures of central tendency and variability.

- Solve real world problems by designing and/or conducting a statistical experiment and by interpreting and communicating the outcome.
- Describe in general terms the normal curve and use its properties to make conjectures about sets of data that are normally distributed.

## Science Foundations Modules (SCF)

Each of the foundation modules in science is designed to develop systematic thinking skills including the ability to formulate questions and plan investigations, collect and interpret data, formulate and revise explanations and models using logic and evidence, analyze alternative explanations and models proposed by others, communicate and defend scientific conclusions.

In addition, each module develops specific concepts and principles that are applicable to a wide variety of situations and teaches participants to apply those concepts and principles to manufacturing-related tasks.

The Science Foundations modules are expected to be developed at the high school level and the advanced modules are to be developed within the associate degree program. The content at the foundation level conforms to the proposed twelfth grade standards of the National Science Education Standards and includes the principles of methods of science, safety and environmental precautions, basic physics mechanics, basic thermal science, and basic chemistry. The college level modules (SCA) extend this background into college-level physics and chemistry.

**Reference:** National Research Council, *National Science Education Standards*, Washington, DC, National Academy Press, 1996.

## Modules

**Note:** The first two modules, Methods of Science and Technology, and Introduction to Safety and Environmental Precautions, are prerequisites for all other science modules.

## Methods of Science and Technology (SCF01)

### *Competencies Developed in This Module:*

- Demonstrate general knowledge of the fundamental principles and processes of science and technology and how they are related.

## Introduction to Safety and Environmental Precaution (SCF02) [10 EHI]

- Apply general safety precautions.
- Understand basic rules of chemical safety.
- Interpret basic components of material safety data sheets (MSDS).
- Explain the basic principles of fire protection related to manufacturing processes.
- Know the general guidelines for chemical waste disposal.
- Explain the purpose of industrial pollution control systems.
- Contrast the financial considerations of preventing pollution to that of cleaning up pollution problems.
- Describe the global pollution problem and develop methods of changing life styles to minimize unnecessary pollution in future generations.
- .Propose action plans for correcting and preventing further pollution.
- Demonstrate an understanding of safety and environmental issues and regulations related to radiation.

### **Prerequisite:** Methods of Science and Technology (SCF01)

## Describing Position, Velocity and Acceleration (SCF03) [10 EHI]

This module introduces participants to the mathematical techniques for describing where an object is located, how its position changes, and how its velocity changes. In addition, participants learn to apply these concepts to technical operations, such as materials handling and robotics.

### *Competencies Developed in This Module:*

- Locate points in three-dimensional space in rectangular coordinates.
- Demonstrate a conceptual understanding of velocity and acceleration as rates of change.
- Prepare and interpret graphs showing the position, velocity, and acceleration of an object.
- Apply the concepts of position, velocity, and acceleration to technical operations, such as materials handling and robotics.

**Prerequisite:** Units and Conversions (MAF01), Equations and Formulas (MAF02)

Forces and Their Effects (SCF04) [10 EHI]

Participants gain an understanding of major types of forces and how those forces affect the velocity of objects, as described by Newton's second law. Participants apply quantitative descriptions of common forces to analyze and control technical operations.

*Competencies Developed in This Module:*

- Apply Newton's second law to predict how one or more forces will change the speed or direction of motion of an object.
- Determine the force or sequence of forces necessary to produce a desired change in motion.
- Apply quantitative descriptions of common forces (friction, normal forces, fluid drag, and gravity) to analyze and control technical operations.

**Prerequisite:** Describing Position, Velocity, and Acceleration (SCF03)

Work and Energy (SCF05) [10 EHI]

*Competencies Developed in This Module:*

- Demonstrate an understanding that all energy can be considered to be either kinetic energy (energy of motion), potential energy (determined by relative position), or energy contained by a field (such as light or other electromagnetic waves).
- Demonstrate an understanding of the principle of conservation of energy.
- Calculate the work done by a force, determine the power, and relate the work to energy change.
- Apply principles of work and energy in analyzing the efficiency of machines and manufacturing operations.

**Prerequisite:** Forces and Their Effects (SCF04)

Equilibrium: Newton's First Law (SCF06) [10 EHI]

*Competencies Developed in This Module:*

- Use vector addition to analyze different systems of forces.
- Calculate and add torques.

- Apply the translational and rotational equilibrium conditions in the analysis of several structural arrangements.

**Prerequisite:** Forces and Their Effects (SCF04)

Properties of Solids (SCF07) [10 EHI]

*Competencies Developed in This Module:*

- Measure basic material properties of solids including density, coefficient of linear expansion, Young's modulus, and breaking strength.
- Demonstrate an understanding of the properties of metals and non-metals in selecting and using materials for a variety of purposes.

Thermodynamics (SCF08) [10 EHI]

*Competencies Developed in This Module:*

- Demonstrate an understanding that energy tends to move spontaneously from hotter to cooler objects by conduction, convection, or radiation, and that any ordered state tends to spontaneously become less ordered over time.
- Apply gas laws to the behavior of gaseous system.
- Measure and apply specific heats, heats of vaporization, etc.
- Demonstrate an understanding of the work-energy transformations involved as a gas expands or is compressed under various conditions.
- Apply the first and second laws of thermodynamics in analyzing the operation of heat engines, refrigerators, and related devices.
- Apply principles of heat transfer in analyzing and improving manufacturing operations.

**Prerequisites:** Units and Conversions (MAF01), Equations and Formulas (MAF02)

Atomic Structure and the Periodic Table (SCF09) [10 EHI]

*Competencies Developed in This Module:*

- Demonstrate an understanding of the Periodic Table, in which repeating patterns of chemical and physical properties are a consequence of the repeating pattern of outermost electrons and their permitted energies.

- Demonstrate an understanding of the theory and properties of metallic materials.
- Apply an understanding of the periodic table in comparing and contrasting the properties of elemental materials widely used in manufacturing.
- Describe the interactions of atoms in terms of the transfer or sharing of electrons.
- Demonstrate an understanding of how the properties of compounds reflect the nature of the interactions among its molecules and how these interactions are determined by the structure of the molecule.
- Explain how the important macroscopic properties of solids, liquids and gases are determined by the nature of the forces between molecules or atoms.
- Identify important real world changes that involve chemical reactions.

**Prerequisites:** Units and Conversions (MAF01), Equations and Formulas (MAF02)

Chemical Kinetics and Equilibrium (SCF10) [10 EHI]

*Competencies Developed in This Module:*

- Apply the kinetic theory to the microscopic behavior of gases.
- Demonstrate an understanding that heat energy consists of random motion and the vibration of atoms, molecules, and ions, and that temperature depends on the amount of atomic or molecular motion.
- Demonstrate an understanding of chemical reaction rates (varying from a few femtoseconds to geologic times scales) and the major factors which influence the rates.
- Demonstrate an understanding of the role of catalysts in accelerating chemical reactions.
- Apply an understanding of reaction rates in analyzing economic, safety and environmental issues in manufacturing.
- Describe and explain properties and concentrations of solutions.
- Read, interpret, and balance chemical equations.

**Prerequisite:** Atomic Structure and the Periodic Table (SCF09)

Oxidation-Reduction Reactions (SCF11) [10 EHI]

*Competencies Developed in This Module:*

- Describe and explain acids and bases and their physical and chemical properties.
- Demonstrate an understanding of acid/base and oxidation/reduction reactions and their applications.
- Describe the current mechanism in batteries and conductors.
- Demonstrate knowledge of corrosion and protection.
- Interpret the “Reactivity Data” included in Material Safety Data Sheets.

**Prerequisite:** Chemical Kinetics and Equilibrium (SCF10)

## Appendix B: Modules

<b>ID</b>	<b>Module</b>	<b>Title</b>	<b>EHI</b>
1	MFG01	Introduction to World-Class Manufacturing	15
2	MAA14	College Algebra with Applications	10
3	MAA01	College Geometry	12
4	MAA02	Vector Analysis	10
5	MAA03	Further Applications of Trigonometry	12
6	MAA04	Precision, Accuracy and Tolerance	10
7	MAA06	Probability	12
8	MAA07	Statistical Distributions	15
9	MAA09	Statistical Experiments	15
10	MAA11	Differentiation	12
11	MAA13	Integration	12
12	SCA01	Rotational Motion and Torque	10
13	SCA02	Momentum	10
14	SCA03	Vibrations and Waves	10
15	SCA04	Optics	10
16	SCA05	Basic DC Circuits	10
17	SCA06	Magnetism and AC Circuits	10
18	SCA07	Fundamentals of Electronics	10
19	SCA08	Organic Chemistry	10
20	SCA09	The Behavior of Fluids	10
21	SCA10	Useful and Hazardous Radiation	10
22	HCT02	Computer Skills	15
23	HCT06	Teamwork	10
24	HCT08	Preparation of Letters and Memoranda	10
25	HCT10	Preparation of Technical and Research Reports	10
26	HCT11	Professional Development	15
27	HCT12	Tools for the Future	30
28	PRP01	Drawing and Sketching	10
29	PRP02	Conceptual Design	15
30	PRP03	Computer Aided Design	15

## Appendix B: Modules (continued)

<b>ID</b>	<b>Module</b>	<b>Title</b>	<b>EHI</b>
31	PRP04	Product Development and Testing	15
32	PRP06	Statics	20
33	PRP07	Strength of Materials	20
34	PRP08	Geometric Dimensioning and Tolerancing	15
35	PIC01	Principles of Production and Inventory Control	15
36	PIC02	Manufacturing Resource Planning	15
37	PIC06	Introduction to Just-in-Time (JIT)	10
38	PIC07	Process Flow and Lead time Reduction	9
39	PIC08	Consistent Work Methods and Build to Demand	10
40	PIC10	Kanban and Pull Systems	10
41	PIC11	Equipment Selection	12
42	PIC12	Manufacturing Work Cell Design	8
43	PIC15	Manufacturing Facilities Design	10
44	QUA01	Quality Foundations	16
45	QUA02	Process Control	10
46	QUA03	Continuous Process Improvement	20
47	QUA04	Measurement and Calibration	16
48	MPM01	Principles of Manufacturing Processes	15
49	MPM02	Basic Material Removal	20
50	MPM03	Metallic Materials	15
51	MPM04	Metal Forming and Joining	15
52	MPM06	Non-Metallic Materials	15
53	MPM07	Plastics Materials and Manufacturing Processes	15
54	MPM08	Tooling for Manufacturing	15
55	MPM05	Heat Treatment/Thermal Processes	15

## Appendix B: Modules (continued)

<b>ID</b>	<b>Module</b>	<b>Title</b>	<b>EHI</b>
56	MPM09	Advanced Machining	15
57	SYS01	Electrical and Electronic Controls	15
58	SYS02	Data Acquisition and Analysis	15
59	SYS03	Fluid Power	15
60	SYS04	Computer Numerical Control	15
61	SYS05	Robots and PLCs	15
62	EIN01	Supply Chain Management	10
63	EIN02	Manufacturing Information Systems	15
64	EIN03	Customer Satisfaction	10
65	EIN04	Financial Management	10
66	EIN05	Performance Measures	15
67	MFG02	Capstone	60
68	ENG111	English Composition I	30
69	ENG112	English Composition II	30
70	COM225	Small Group Communication	30
71	PSY129	Work Group Dynamics (Soc. Sci.)	30
72	HUM132	Conn. Technology and Our Lives (Humanities)	30
73	HUMxxx	Humanities Elective	30
		Total EHI	1111