Industrial Engineering Technology Curriculum Remapping

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Abstract

Industrial Engineering Technology curriculum generally provides wide spread knowledge in problem solving, management of resources, and process planning. This paper remaps a typical Industrial Engineering Technology curriculum to align it with the four pillars of manufacturing knowledge (as identified by the Society of Manufacturing Engineers). A case study approach is used to take the courses of an Industrial Engineering Technology program, and develop an as-is curriculum map. After that, a gap analysis is performed against the four pillars of manufacturing knowledge. The gap analysis is used to suggest modifications to the Industrial Engineering Technology curriculum, including addition of courses and/or modifying existing course contents. The paper concludes with a phased implementation plan to align the selected Industrial Engineering Technology program with the four pillars of manufacturing knowledge.

Introduction and Background

The National Academy of Engineering forecasts that engineers and technologists will continue to operate in a rapidly changing innovation environment. This is compounded by globalization of economies, diversity of social and business groups, multidisciplinary research trends, and cultural and political forces. Engineering systems are of increasing complexity in energy, environment, food, product development, and communications. Hence, it is imperative to introduce engineering and technology practices in undergraduate education, where students can experience the iterative process of designing, analyzing, building and testing. There is a growing importance for engineering practice, but the engineering profession seems to be held in low regard compared to other professions and industry tends to view engineers and technologists as disposable commodities.

Industrial Engineering Technology prepares “graduates with the technical and managerial skills necessary to develop, implement, and improve integrated systems that include people, materials, information, equipment, and energy”. To do so, a typical Industrial Engineering Technology curriculum provides widespread knowledge in problem solving, management of resources, and process planning. Specifically, “graduates must demonstrate the ability to accomplish the integration of systems using appropriate analytical, computational, and application practices and procedures... must demonstrate the ability to apply knowledge of probability, statistics, engineering economic analysis and cost control, and other technical sciences and specialties necessary in the field of industrial engineering technology”. According to ABET, manufacturing deals with value-added transformations in shape, form or properties of materials. The specific ABET ETAC student outcomes for Engineering Technology are:

a. An ability to select and apply the knowledge, techniques, skills, and modern tools of the discipline to broadly-defined engineering technology activities
b. An ability to select and apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require the application of principles and applied procedures or methodologies
c. An ability to conduct standard tests and measurements; to conduct, analyze, and interpret experiments; and to apply experimental results to improve processes
d. An ability to design systems, components, or processes for broadly-defined engineering technology problems appropriate to program educational objectives
e. An ability to function effectively as a member or leader on a technical team
f. An ability to identify, analyze, and solve broadly-defined engineering technology problems
g. An ability to apply written, oral, and graphical communication in both technical and non-technical environments; and an ability to identify and use appropriate technical literature
h. An understanding of the need for and an ability to engage in self-directed continuing professional development
i. An understanding of and a commitment to address professional and ethical responsibilities including a respect for diversity
j. A knowledge of the impact of engineering technology solutions in a societal and global context
k. A commitment to quality, timeliness, and continuous improvement

The four pillars is a common model of the manufacturing engineering field, and it may serve as a foundation for continuous improvement of manufacturing-related curricula, such as Industrial Engineering Technology. The four pillars are: 1) Materials and Manufacturing Processes, 2) Product, Tooling, and Assembly Engineering, 3) Manufacturing Systems and Operations, and 4) Manufacturing Competitiveness. Additional usages of the four pillars model include:
- Dialogues between program constituents and curriculum designers to ensure that graduates possess knowledge and skills in manufacturing principles and practices
- A starting point for defining the field of manufacturing engineering
- Assessing job applicants to manufacturing-related jobs
- Designing in-house training for employees

The four pillars model suggests that manufacturing knowledge-based curriculum should include components in the following areas:
- Product, Tooling, and Assembly Engineering
- Manufacturing Systems and Operations
- Manufacturing Competitiveness
- Math and Science
- Personal Effectiveness
- Engineering Science
- Materials
- Manufacturing Processes
- Product Design
- Process Design
- Equipment/Tool Design
- Production System Design
- Automated Systems and Control
- Quality and Continuous Improvement
- Manufacturing Management
The field of manufacturing is wide, and engineering technologists must understand the manufacturing processes and materials involved in the creation of a useful product. Hence, adopting a unifying model such as the four pillars may aid in streamlining the pipeline in preparing future manufacturing engineers and technologists. The emergence of non-traditional education providers (such as online and hybrid) poses challenges for US higher education institutions. To remain competitive, US universities should re-adapt the way education is delivered, and develop curricula that meets the core competencies required in the market place. At a time when local, state, and national resources for education are becoming increasingly scarce, expectations for institutional accountability and student performance are becoming more demanding. There is a need for more educational innovations that have a significant impact on student learning and performance. The dominant approach for engineering and engineering technology education in the US is based largely on faculty intuition drawn from personal experiences as students and teachers.

This research takes a pragmatic approach to reshape a curriculum of an Industrial Engineering Technology program. It uses the four pillars of manufacturing knowledge to suggest improvement opportunities. The paper proceeds by discussing the method used to carry out the research. After that it provides a summary of the results. The paper concludes by a discussion of the key findings and how to proceed in implementing the identified changes to the curriculum.

**Method**

This paper uses a case-study approach. The curriculum of an Industrial Engineering Technology program from a university in Louisiana is selected. A faculty team of the Engineering Technology department reviewed the university documentation and catalog information (including course descriptions and dependencies, course syllabi, course competencies, and course assignments) to develop a curriculum map in flowchart format. The faculty team used course descriptions, syllabi, competencies and assignments to link the courses of the selected Industrial Engineering Technology program to the four pillars of manufacturing knowledge. After that, a matrix approach is used to conduct a gap analysis of the selected Industrial Engineering Technology program against the components of the four pillars of manufacturing knowledge model. The gap analysis is used to identify opportunities of improvement and suggest changes to course descriptions and possible courses to add to selected Industrial Engineering Technology curriculum. The suggested improvements are used to create a revised curriculum map and a plan to implement the recommendations.
Results and Discussion

The selected Industrial Engineering Technology program has both major and support courses to prepare graduates for technical and supervisory careers in a variety of industries. The program combines technical knowledge with communications skills and teamwork to provide the flexibility needed in today’s rapidly changing marketplace. Figure 1 depicts an as-is curriculum map of the selected Industrial Engineering Technology program. The selected program educational objectives are:

- Demonstrate technical proficiency in the field
- Apply quantitative reasoning and critical thinking in solving technical problems
- Effectively communicate technical knowledge, ideas, and proposals to others, including upper management
- Lead project teams in successful completion of projects
- Have strong organizational and management skills

A brief description of some of the courses is as follows (as an example):

- **Electronic Fabrication Lab**: Fabrication techniques for analog and digital circuits. Device symbols and markings, soldering, antistatic techniques, measurement, testing and troubleshooting.
- **Electrical Principles II**: Alternating current. Capacitors, inductors, and impedance. AC circuit analysis theorems and techniques.
- **Engineering Tools and Dimensional Analysis**: Principles and practices of measurement technology; use of tools; dimensional analysis; and the use of all the above in applications of technology.
- **Technical Drafting I and II**: Introduction to drafting, with computer-aided drafting (CAD) applications. Orthographic projection, geometric construction, sectioning, dimensioning, auxiliary views, and text.
- **Introduction to Engineering Technology**: Specific information for engineering technology students about degree requirements, scholastic resources, careers in engineering technology, job opportunities, academic skills for success in engineering technology, scholarship, and preparing for the future.
- **Occupational Safety and Health**: Principles and practices of accident prevention and safety program operation in industrial facilities and school laboratories; effective safety organization, management and supervision; teacher, administrator and management liabilities; Occupational Safety and Health Act (OSHA).
- **Metals Machining I**: Machine tool technology; operator control and computer numerical control (CNC) machining, computer-aided manufacturing (CAM), and production centers. Survey of nontraditional machining processes.
- **Engineering Materials**: Methods of making basic engineering materials; phase diagrams; crystalline lattice structures; material properties; methods for changing material properties.
- **Statics**: Principles of statics, vector algebra and vector quantities. Resultants in coplanar force systems, equilibrium in coplanar force systems, analysis of structures, trusses, beams, chains and cables, friction, centroids and centers of gravity, moments of inertia.
Figure 1. As-Is Curriculum Map of Selected Industrial Engineering Technology Program
• Fluid Power: Compressible and incompressible fluid statics and dynamics of industrial hydraulic and pneumatic circuits and controls. Software and functional components used to design, construct, and analyze piping circuits.
• Motion and Time Study: Analysis of motions necessary to perform industrial operations; motion economy; development of ratings, allowances, standard data, formula construction, work sampling, wage payment and performance training.
• Material Handling: Material handling as related to manufacturing, warehousing and distribution centers. Topics include methods of movement, storage, inventory control, and retrieval.
• Engineering Economics: Principles and applications of economic analysis presented through engineering-oriented examples. Introduction and definitions of economic factors, analysis methods for evaluating alternative choices, and decision making tools for real-world situations.
• Manufacturing Facilities: Study of the planning processes for facilities location and design, material handling equipment, and manpower requirements. Analysis of production line requirements, assembly line balancing, and automation.
• Quality Control: Methods and procedures employed in industrial quality control, theories of measurement, error, prediction, sampling, tests of significance and models.
• Elements of Occupational Supervision: Preparation, training, and problems of the supervisor.
• Project Design I: Principles of project management and engineering economics. Development of proposals for senior design project.
• Project Design II: This is a capstone course for engineering technology majors. Students will work with a professor to design a project that reflects several aspects of the student’s curriculum. Group work. Students will prepare a written project report and give an oral presentation.

The courses from the selected Industrial Engineering Technology program are mapped to the components of the four pillars of manufacturing knowledge (e.g., Materials and Manufacturing Processes, etc.), and the results are depicted in Table 1. The shaded areas indicate opportunities for improvement. The areas of improvement have 3 or fewer X’s, indicating alignment with 3 or less components, within the selected Industrial Engineering Technology program. Specifically, there seems to be a need to incorporate additional content to the selected Industrial Engineering Technology curriculum in:
• Personal Effectiveness
• Materials
• Manufacturing Processes
• Product Design
• Production System Design
• Automated Systems and Control
The following items are suggested:
- Adding a course on Operations Management to address Product Design, Manufacturing Processes, and Production System Design
- Adding a course on Process Control to address Automated Systems and Control
- Incorporating content in the existing Metal Machining I course related to Materials
- Providing teamwork, written reports, and presentation experiences in Quality Control, Engineering Economics, and Occupational Supervision to enhance Personal Effectiveness

Once implemented, these changes to the selected Industrial Engineering Technology curriculum will bring it closer to meeting the needs suggested the four pillars of manufacturing engineering model. The changes will be implemented in a phased approach, where modifications to existing courses will be documented in course syllabi and descriptions. This will require incorporating student assessment metrics related to Personal Effectiveness and Materials within the courses. After that, the courses on Operations Management and Process Control will be added to the curriculum, along with proper prerequisites and student assessment metrics. In order to add the courses, they will be first discussed with the Industry Advisory Committee, and other program constituents. Currently, the selected Industrial Engineering Technology program requires three electives; hence adding the courses on Operations Management and Process Control will not result in reducing the content of courses somewhere else. The reduction of amount of electives may result in a loss to the customization available to students pursuing the Industrial Engineering Technology degree, and future program revisions with input from the Industry Advisory Committee, and other program constituents, will examine options to restore program customization and flexibility.
Table 1. Gap Analysis of the Selected Industrial Engineering Technology Curriculum

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