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Development of a Multi-skilled Craftsman Program Through Collaboration Between Industry, Technical Community College, and Four-year University

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Abstract

Engineering Technology curriculum generally provides wide spread knowledge in problem solving, management of resources, and process planning. An Industry Advisory Council for a university in Louisiana expressed the need for multi-skilled craftsman trained graduates, and worked with Engineering Technology faculty to develop an associate of science degree program, in collaboration with a local technical community college, that is focused on advanced manufacturing.

This paper discusses the development of an industry-driven program on advanced manufacturing. The program is implemented as a collaborative offering by a university in Louisiana and a neighboring technical community college. The developed program combines the strengths of complementary offerings to prepare multiskilled craftsmen. The program is implemented in a work-study format, where students go to classes two days per week, and work three days per week at a manufacturing facility. The paper starts by identifying the need for multiskilled craftsman training. After that it discusses the key components for multiskilled craftsman preparation: Safety, basic electrical and mechanical maintenance, welding, and automation. These components led to putting together an 80-hour 2-year curriculum that enables graduates to obtain an associate of science degree in engineering technology along with a certificate as maintenance technician. The paper concludes by providing directions for future development of the new program.

Introduction and Background

The National Academy of Engineers forecasts that engineers and technologists will continue to operate in a rapidly changing innovation environment[1]. 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[1]. 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[2].

An Associate of Science in Engineering Technology prepares graduates with knowledge skills and technical problem-solving abilities necessary to success in a wide range of engineering technology disciplines[3]. The specific ABET ETAC student outcomes for Associate of Science in Engineering Technology are[3]:

a. an ability to apply the knowledge, techniques, skills, and modern tools of the discipline to narrowly defined engineering technology activities;

b. an ability to apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require limited application of principles but extensive practical knowledge;
c. an ability to conduct standard tests and measurements, and to conduct, analyze, and interpret experiments;
d. an ability to function effectively as a member of a technical team;
e. an ability to identify, analyze, and solve narrowly defined engineering technology problems;
f. 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;
g. an understanding of the need for and an ability to engage in self-directed continuing professional development;
h. an understanding of and a commitment to address professional and ethical responsibilities, including a respect for diversity; and
i. a commitment to quality, timeliness, and continuous improvement.

The field of manufacturing is wide, and engineering technologists must understand the processes and materials involved in the creation of a useful product[4]. 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[5]. 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[6].

An industrial advisory council approached an engineering technology department at a University in Louisiana with a need to develop a new program that produces multiskilled maintenance professionals. This program was named Advanced Manufacturing Technician. In the Louisiana Workforce Commission’s Jobs listing, there are approximately 300+ advertisements for technician jobs[7] (accessed on 5/20/2017). With this new certificate program, it is expected that students with an associate degree and a technical certificate will fill several multi-skilled maintenance personnel positions in manufacturing industries.

This research takes a pragmatic approach to develop an industry driven certificate program through collaboration between a 4-year university and a technical school. 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 provide directions for future development of the new degree program.

Method

This paper uses a case-study approach. Based on needs identified by a manufacturer managers' council, a faculty team of the Engineering Technology department worked with members of their industry advisory committee to develop a new collaborative associate degree program that uses courses from a 4-year university and additional courses from a near-by technical college. The team researched similar programs available nationwide, reviewed the university documentation and catalog information (including course descriptions and dependencies, course syllabi, course competencies, and course assignments), and technical college course information. The team identified the knowledge areas required by a holder of the new program, which was named Advanced Manufacturing Technician. The graduates of the Advanced Manufacturing Program obtain an Associate of Science in Engineering Technology (with a concentration in Advanced Manufacturing) from the 4-year university and a technical certificate from the technical college.

Results and Discussion

The selected Engineering Technology program has both major and support courses to prepare graduates for technical 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. 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

Several institutions nationwide provide training programs in advanced manufacturing, such as:

- Jackson State Community College[8]
- Vincennes University[9]
- Alamo College (TX FAM)[10]
- Itawamba Community College[11]
- Calhoun Community College[12]

The reviewed programs were initiated by one big manufacturer, while the developed program involved a consortium of companies with varied skilled technician needs. The participating companies include:

- Alliance Compressors
- Boise Cascade
- Roy O Martin
- Stella Jones
- Pilgrims

Reviewing the advanced manufacturing technicians' curricula resulted in identifying the following key knowledge areas:

- Safety Culture
- Welding
- Electrical/Mechanical Maintenance
- Automation and Control

The analysis of these curricula resulted in identifying the need for combining course offerings of a 4-year university and a nearby technical college. For the 4-year university, an associate of science degree requires a minimum of 60 credit hours (of which about half is university core courses such as Composition, Algebra, and Social Science). A technical certificate requires a minimum of 18 hours. *The number of hours for each program was determined by the requirements established by the institute's governing body.* Based on these constraints, the following 2-year program was developed and approved by each institution's curriculum committee, see Table 1.

Table 1. Advanced Manufacturing Technician Curriculum (Sessions I and II refer to the two six seeks summer sessions at the 4-year university)

First Year					
Fall Semester			Spring Semester		
Course		Credits	Course		Credits
IET 1020	Engineering Tools and Dimensional Analysis	3	IET 2400	Technical Drafting II	3
IET 1400	Technical Drafting I	3	EET 1320/1321	Electrical Principles II / Lab	4
EET 1300/1301	Electrical Principles I / Lab	4	MATH 1090	Trigonometry	3
UNIV 1000	The University Experience	1	COMM 1010	Fundamentals of Speech	3
ENGL 1010	Composition and Rhetoric I (on-line course)	3	ADMT 1110	Workplace Organization (5S)	1
MATH 1020	College Algebra	3	ADMT 1115	Fluid Power	3
ADMT 1100	Safety Culture	1			
Total		18	Total		17
Summer Session					
Session I & II					
Course		Credits			
EET 1330/1331	Digital Electronics I / Lab	4			
ENGL 1020	Composition and Rhetoric II (on-line course)	3			
ADMT 1120	Introduction to Electric Motor Controls	3			
ADMT 1125	Welding for Maintenance	3			
ADMT 1200	Lean Manufacturing	1			
Total		14			
Second Year					
Fall Semester			Spring Semester		
Course		Credits	Course		Credits
IET 2920	Special Problems (Problem Solving I)	2	IET 2020	Metal Machining I	3
EET 2320/2321	Basic Electronics / Lab	4	EET 3320	Electric Motor Controls	3
FA 1040	Fine Arts	3	SCI 1020	Basic Concepts of Biological Science I	3
SCI 1010	Basic Concepts of Physical Science I	3	PSYC 1010	General Psychology	3
ADMT 1210	Programmable Logic Controllers	3	ADMT 1230	Integrated Control Systems	3
			ADMT 1240	Problem Solving II	1
			ADMT 1250	Maintenance Reliability	1
Total		15	Total		17

In Table 1, the courses indicated by the ADMT prefix are offered through the technical college, while the remining courses are offered by the 4-year university. The associate of science in advanced manufacturing is designed as a work-study program, where students attend classes full time two days a week and work (paid) at a sponsoring manufacturer site for the remaining three days. At the time of this manuscript, six manufacturers are supporting more than 16 concurrent students. The students also learn essential manufacturing principles and develop productive work behaviors that provide excellent self-development skills that are very attractive to employers.

The curriculum implements the multidisciplinary, multiskilled model with courses in electricity, fluid power, mechanics, fabrication, troubleshooting, problem solving, etc. The graduates of the program can pursue employment at any of the participating manufacturers or other local or national manufacturers.

The following is a listing of the required courses along with descriptions for the developed Advanced Manufacturing Technician program (organized by semester):

- Fall – Semester 1
    - IET 1020. 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.
    - IET 1400. TECHNICAL DRAFTING I. Introduction to drafting, with computer-aided drafting (CAD) applications. Orthographic projection, geometric construction, sectioning, dimensioning, auxiliary views, and text. Includes display and editing techniques as well as working with drawing files.
    - EET 1300 / 1301. ELECTRICAL PRINCIPLES I / LAB. Principles governing current, voltage, resistance and power in DC circuits. Series, parallel, and series-parallel circuits. Network theorems.
    - UNIV 1000. THE UNIVERSITY EXPERIENCE. This course is designed to ease students' transition to the University experience. The focus is primarily on career development, the academic advising process, and academic regulations/requirements. New students will be exposed to a wealth of University programs and services, including, but not limited to: engagement in student affairs, financial aid regulations, Department of Education compliance, and awareness of the numerous student organizations and activities at Northwestern State University.
    - ENGL 1010. COMPOSITION AND RHETORIC (ON-LINE). The short paper; rhetoric, with emphasis on writing.
    - MATH 1020. COLLEGE ALGEBRA. A graphing treatment of the essential topics of college algebra with emphasis on functions, graphing, and applications.
    - ADMT 1100. SAFETY CULTURE. Introduces the importance of cultivating daily safe work habits and the predictable negative results of not being safety conscious in the work place. Instructs the students in basic safety culture and prepares them to participate in, conduct, and lead safety walk-throughs. Introduces the student to Hazard Prediction Training. Prepares the student to conduct risk assessment activities, construct safety boards, and formulate individual safety commitments.
- Spring – Semester 2
    - IET 2400. TECHNICAL DRAFTING II. Continuation of IET 1400, with intermediate CAD applications. Working drawings, limit dimensioning, threads and fasteners, secondary auxiliary views, descriptive geometry, assembly drawings, and production illustrations.
    - EET 1320 / 1321. ELECTRICAL PRINCIPLES II / LAB. Alternating current. Capacitors, inductors, and impedance. AC circuit analysis theorems and techniques.
    - MATH 1090. TRIGONOMETRY. Trigonometric functions; relations between functions; solution of triangles with applications to practical problems; trigonometric formulas and identities; radian measure; graphic representation of trigonometric functions; inverse trigonometric functions, trigonometric equations.
    - COMM 1010. FUNDAMENTALS OF SPEECH. Development of desirable habits for normal speech situations; effective use of voice, oral language, and bodily actions; basic principles of speech composition.

    - ADMT 1110. WORKPLACE ORGANIZATION (5S). Introduces the fundamental 5S process involving the five-step progression of sort, set in order, shine, standardize and sustain. Instructs the students in the sequence involving classifying and sorting, ordering and aligning, cleaning and sweeping up, standardizing, and developing a process of
    - sustainable practice in the workplace. Fosters the development of a workplace organization in which safety and efficiency are always paramount.
    - ADMT 1115. FLUID POWER. Explains the fundamental concepts of fluid power and electro-fluid power systems, primarily with pneumatic and hydraulic systems. Covers the principles of fluid power, calculations of physical properties of fluids and their ability to do work. Introduces the various fluid power components, symbols, circuits. Introduces troubleshooting of fluid power components and systems with an emphasis on safety. Addresses fluids, filters, reservoirs, piping, pumps, actuators, accumulators, control valves, and combination circuits.
- Summer – Semester 3
    - EET 1330 / 1331. DIGITAL ELECTRONICS I / LAB. Logic functions, logic gates, number systems and conversions, Boolean algebra, logic simplification, combinational circuits, programmable logic devices, and flip-flops. Analysis and design of basic digital logic circuits.
    - ENGL 1020. COMPOSITION AND RHETORIC II (ON-LINE). Writing the longer paper; diction, style, analysis and interpretation of collateral readings leading to the composition of the research paper.
    - ADMT 1120. INTRODUCTION TO ELECTRIC MOTOR CONTROLS. An introduction to basic manual and push button motor control systems. Topics include an understanding of ladder logic and its various components, and basic motor and control installations.
    - ADMT 1125. WELDING FOR MAINTENANCE. Provides basic instruction needed for student to weld using SMAW (Stick), GMAW (MIG), GTAW (TIG), and Oxy-Fuel processes.
    - ADMT 1200. LEAN MANUFACTURING. Instructs the student in the concepts of value-added product, maintenance value-added product, value-added work and necessary work. Explains the process of how a business earns profit. Demonstrates the Toyota Production System for Maintenance using the House framework. Describes and explains Muda (waste), Muri (overburden) and Mura (unevenness) as well as the seven Muda waste areas (overproduction, waiting, transporting, inappropriate processing, unnecessary inventory, unnecessary / excess motion and defects) and their relationship to maintenance and production.
- Fall – Semester 4
    - IET 2920. SPECIAL PROBLEMS. Problem Solving I. Introduces the Toyota Business Practice model, the 8 step Toyota Problem Solving method, and the 10 part Toyota Drive and Dedication model. Instructs the students to clarify the problem, break it down to analyze it, set achievable targets, analyze the root cause, develop countermeasures, evaluate results and the process, standardize the results, and learn from failures. Fosters the development of a customer first philosophy involving all the stakeholders.
    - EET 2320 / 2321. BASIC ELECTRONICS / LAB. Principles of semi-conductor devices and circuits. Design and analysis of diode and bipolar junction transistor in switching and amplifier circuits.
    - FA 1040. FINE ARTS. The fine arts (music, visual art, drama, and dance) as they relate to the human experience.
    - SCI 1010. BASIC CONCEPTS OF PHYSICAL SCIENCE I. Basic concepts of physics and chemistry.

    - ADMT 1210. PROGRAMMABLE LOGIC CONTROLLERS. Introduces Programmable Logic Controllers (PLC) and elements needed for an automated industrial control system. Introduces memory and project organization within a PLC and provides instruction in basic numbering systems, computer and PLC terminology. Introduces PLC control functions, program structures, language standards, wiring and troubleshooting methods, as well as, real world
    - communications. Requires the student to program a PLC which may include a combination of ladder logic, structured text, sequential function chart and/or function block languages. Includes various protocols of industrial communications used between PLC controlled machines, PLC to PLC, PLC to computer, and computer to computer.
- Spring – Semester 5
    - IET 2020. METALS MACHINING I. Machine tool technology; operator control and computer numerical control (CNC) machining, computer-aided manufacturing (CAM), and production centers. Precision measurement and layout. Survey of nontraditional machining processes.
    - EET 3320. ELECTRIC MOTOR CONTROLS. Theory of operation of electric motors with emphasis placed on ac motors in terms of circuit diagrams and safety. Basics of industrial motor controls, sensors and control devices, electronic control of direct-current (DC) motors, electronic control of alternating-current (AC) motors, manual contactors, magnetic motor starters, and installation of control devices and maintenance procedures.
    - SCI 1020. BASIC CONCEPTS OF BIOLOGICAL SCIENCE I. Chemical basis of life, cell structure and specialization, cellular respiration, photosynthesis, patterns of inheritance, nature and action of genes, simplified classification and evolution of plants, and organismic processes.
    - PSYC 1010. GENERAL PSYCHOLOGY. Principles of psychology; human behavior; shaping of behavior and personality by interaction between individual and environment.
    - ADMT 1230. INTEGRATED CONTROL SYSTEMS. Develop skills on the manufacturing cell line to integrate the function and application of hydraulic, pneumatic, mechanical, electrical and robotic components with the use of programmable logic controllers and other control devices, including Human Machine Interface (HMI) operator display panels.
    - ADMT 1240. PROBLEM SOLVING II. Student teams apply their technical, problem solving, presentation and communication skills to address a manufacturing process improvement and present their project to a panel of manufacturing officials. Successful presentations will incorporate prior learning outcomes into a single integrated learning experience.
    - ADMT 1250. MAINTENANCE RELIABILITY. Introduces the Toyota Maintenance Reliability training. Describes the difference between corrective maintenance and preventive maintenance. Breaks down proactive maintenance and the underlying tools and constituent processes. Instructs the students in the various individual units in a system and the steps in evaluating failure mode risks and countermeasures.

Some of these courses (those related to the university core) are already offered both online and face-to-face by the 4-year university. The availability of the online course options helps balance the load distribution of this 2-year program on students.

The manufacturers, technical college and the 4-year university established the following requirements for the developed Advanced Manufacturing Technician program:

- 18 years of age at the start of the program
- High school graduate at the start of the program (cohorts begin each Fall Semester)

- U.S. Citizen (this requirement was established by manufactures to ensure employability of students in their facilities)
- Demonstrate academic success as measured through grades and class rank
- Demonstrate math capability measured through ACT/SAT scores (minimum of 19 ACT)
- Certification for Manufacturing (C4M), Project Lead the Way (PLTW), and Wood Works participation as measured by number of course taken and the grades earned; these courses are not required, but because of the skills acquired by participating in these courses, it improves chances of selection
- Submission of a written essay

Additionally, to complete the program, students must:
- Commit to remain absolutely illegal drug-free
- Fulfill all 4-year university requirements for the Associate of Science in Engineering Technology requirements
- Fulfill all the technical college course requirements
- Maintain minimum of "C" or higher in all courses throughout the program
- Minimum of "Satisfactory" on all work evaluations throughout the program
- Meet program expectation as outlined in the Commitment Form that will be distributed at program orientation

An assessment plan was developed for the new degree program that is consistent with ETAC of ABET requirements for Student Learning Outcomes (SLO), as shown in Table 2. This plan is currently a draft, and will be revised to consider other course mappings/assessment tools.

Table 2. Assessment Plan for the Advanced Manufacturing Technician Program

Student Learning Outcome	Course Mapping	Assessment Tool (s)
SLO 1. Ability to apply the knowledge, techniques, skills, and modern tools of the discipline to narrowly defined engineering technology activities (ETAC of ABET Outcome a).	EET 1321: ELECTRICAL PRINCIPLES II LAB IET 1400: TECHNICAL DRAFTING I	Students' grades on the EET 1321 Final Exam are used to assess the attainment of SLO 1. The acceptable target is 80% of students score C or better on final examination. A rubric for IET 1400 (under development) is used to evaluate student attainment of SLO 1. The acceptable target is 80% of students rated at least at acceptable level.
SLO 2. Ability to apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require limited application of principles but extensive practical knowledge (ETAC of ABET Outcome b).	EET 1320: ELECTRICAL PRINCIPLES II IET 1400: TECHNICAL DRAFTING I	Students' grades on the EET 1320 Final Exam are used to assess the attainment of SLO 2. The acceptable target is 80% of students score C or better on final examination. A rubric for IET 1400 (under development) is used to evaluate student attainment of SLO 1. The

		acceptable target is 80% of students rated at least at acceptable level.
Ability to conduct standard tests and measurements, and to conduct, analyze, and interpret experiments (ETAC of ABET Outcome c).	EET 1321: ELECTRICAL PRINCIPLES II LAB	Students' grades on the EET 1321 Final Exam are used to assess the attainment of SLO 3. The acceptable target is 80% of students score C or better on final examination.
SLO 4. Ability to function effectively as a member of a technical team (ETAC of ABET Outcome d).	EET 1321: ELECTRICAL PRINCIPLES II LAB	Students' grades on the EET 1321 Laboratory Reports are used to assess the attainment of SLO 4. The acceptable target is 80% of students receive C or better on technical component of formal laboratory report.
SLO 5. Ability to identify, analyze, and solve narrowly defined engineering technology problems (ETAC of ABET Outcome e).	EET 1320: ELECTRICAL PRINCIPLES II IET 1400: TECHNICAL DRAFTING I	Students' grades on the EET 1320 Final Exam are used to assess the attainment of SLO 5. The acceptable target is 80% of students score C or better on final examination. A rubric for IET 1400 (under development) is used to evaluate student attainment of SLO 5. The acceptable target is 80% of students rated at least at acceptable level.
SLO 6. 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 (ETAC of ABET Outcome f).	COMM 1010: FUNDAMENTALS OF SPEECH	Student's final grades on COMM 1010 are obtained through institutional research. The acceptable target is 80% of graduating students graded C or better in course COMM 1010.
SLO 7. An understanding of the need for and an ability to engage in self-directed continuing professional development (ETAC of ABET Outcome g).	IET 1400: TECHNICAL DRAFTING I	A rubric for IET 1400 (under development) is used to evaluate student attainment of SLO 7. The acceptable target is 80% of students rated at least at acceptable level.
SLO 8. An understanding of and a commitment to address professional and ethical responsibilities, including a respect for diversity (ETAC of ABET Outcome h).	IET 1400: TECHNICAL DRAFTING I EET 1320: ELECTRICAL PRINCIPLES II	A rubric for IET 1400 (under development) is used to evaluate student attainment of SLO 8. The acceptable target is 80% of students rated at least at acceptable level. Students' grades on the EET 1320 Final Exam are used to assess the attainment of SLO 8. The acceptable target is 80% of students score C or better on final examination.
SLO 9. A commitment to quality, timeliness, and continuous improvement (ETAC of ABET Outcome i).	IET 1400: TECHNICAL DRAFTING I	A rubric for IET 1400 (under development) is used to evaluate student attainment of SLO 9. The

	EET 1320: ELECTRICAL PRINCIPLES II	acceptable target is 80% of students rated at least at acceptable level. Students' grades on the EET 1320 Final Exam are used to assess the attainment of SLO 9. The acceptable target is 80% of students score C or better on final examination.

Conclusions

This paper described the development of an industry-driven program on advanced manufacturing. The resulting program is offered through a partnership between a technical college and a 4-year university. The complementary strengths and course offerings of both institutions were needed to satisfy the identified key knowledge areas of: Safety Culture, Welding, Electrical/Mechanical Maintenance, and Automation and Control. Graduates from program will earn an Associate of Science in Engineering Technology (60 hours, with a concertation in Advanced Manufacturing) from the 4-year university, and a Technical Certificate (20 hours) from the technical college.

Future directions for the development of the program include:

- Finalize the assessment plan for attainment of SLOs
- Develop mentoring plans that link course instruction with on-site work assignments
- Formalize memorandum of understanding between manufacturers, technical college and 4-year university (some are already in-place)
- Develop marketing material and continue program promotion
- Establish local and regional chapters for manufacturers involved in the program
- Develop and implement a time-line for program specific recruiting efforts (driven by manufacturers)

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