7-26-2021

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2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #34095

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Abstract

The University of Texas Rio Grande Valley (UTRGV) has consolidated BS degree programs in Manufacturing Engineering Technology, Mechanical Engineering technology and Electronics Engineering Technology into a generic BS Engineering Technology program with specialization in Mechatronics and Industrial Automation. This paper reports on the work in progress to align the program to meet the changing needs of the industries in the era of Industry 4.0. The recent consolidation of majors in the Engineering Technology (ET) program provide us with a rare opportunity to enhance the program for students, faculty, college, and industry. We discuss program enrichment through the inclusion of skill-based industry recognized certifications that are embedded in the regular ET curriculum as laboratory extensions in four areas, such as: Computer Aided Design (CAD), Computer Numerical Control (CNC), Dimensional Metrology - Coordinate Measuring Machine (CMM), and Industrial Robots.

Introduction

The Fourth Industrial Revolution (Industry 4.0) is challenging the industries to change the way they manage and operate the manufacturing environment. This leads to the transformation of the world through artificial intelligence, next-generation robotics, automation, big data analytics, 5G technology and Internet of Things. This idea of Industry 4.0 forces the change in the industries of today and tomorrow. In this, cyber physical systems communicate with one another using the Internet of Things. The manufacturing sector takes full advantage of these technologies to produce innovative products to enhance the human experience. Contrary to the prediction of huge job loss due to these new technologies, more jobs are being created at a rapid pace. This is evident in the number of job openings growing at double-digit rates since mid-2017. This trend created a new set of problems in finding a matching workforce that will support the growing areas of advanced manufacturing in digital talent, skilled production and operational managers. The digital talent includes programming and managing a pool of computer-enabled machines and equipment.

According to the study by Deloitte and the Manufacturing Institute (1), the skills needed in the above areas may leave an estimated 2.4 million positions unfilled between 2018 and 2028, with a potential economic impact of $ 2.5 trillion. Further, the study shows that the positions relating to digital talent, skilled production, and operational managers may be three times as difficult to fill in the next three years.

Skilled Workforce for 21st Century Manufacturing

The US is facing an alarmingly high replacement need for STEM professionals (2, 3). For instance, the projected replacement rate in mathematical science is 29.5%, in physics it is 28.5%, in mechanical engineering it is 26%, and in electrical engineering it is 23%. It is estimated that during this decade, employers will need to hire about 2.5 million skilled STEM workers, drawing largely from engineering and engineering technology programs that are known for equipping graduates with the tools to enter the engineering and technology workforce (4). This requires an innovative curriculum that involves hands-on opportunities for practical problem solving. While robotics can be used as an interdisciplinary STEM learning tool, there is also a strong need for industrial certification programs in robotics automation. Millions of domestic/personal robots are already on the market worldwide, from lawn mowers to entertainment robots. Global competition, productivity demands, advances in technology, and affordability will force companies to increase the use of robots in the foreseeable future (5-8). While the automotive industry was the first to use robotics, aerospace, machining, and medical industries now also rely on robotic automation (9, 10). More than ever, trained and certified specialists are needed to maintain and monitor existing robots and to develop more advanced robotic technologies (11, 12-14). Robotics education coupled with advance manufacturing technologies play a key role in preparing a workforce to implement 21st century technologies (10,23,24). Currently, there are several universities offer specific robotics degrees. However, very few universities across the US offer a degree and/or certification specifically in robotics automation. Similarly, there exists a need for certifications in CAD software, CNC and Coordinate Metrology for the advanced manufacturing industry.

The UTRGV has undertaken an initiative to address the growing needs of skilled human power in these critical areas that are very important for the local industries to sustain the competitive edge in the global manufacturing environment. Industries often look for graduates that are ready to be employed with minimum on the job training. The certifications offered by the professional institutions serve as the enabling tool for industries to assess the potential of newly minted graduate who have minimum field experience.

This paper presents the details on the innovative development of the embedded engineering technology curriculum with industry recognized certifications in the much-needed areas of Industry 4.0. This will invariably help the industries to mitigate the difficult-to-fill workforce needs in the critical areas of advanced manufacturing. Also, discussed in detail in the paper are the pedagogical aspects of the Engineering Technology curriculum and the seamless integration of industry recognized certifications that have the potential to enhance the marketability of its graduates.

Project Overview and Objectives

The overall goal of the project is to prepare the engineering technology graduates to meet the need for highly trained technician/technologist in the Industry 4.0. Strategies include developing, model curriculum, that enables certifications as part of the regular curriculum as well serve as the standalone certifications for students, veterans and industry personnel that want to retool to match their skills for advance manufacturing industries.

Specific project objectives include the following:

1. Provide Engineering Technology 4-year students at UTRGV with current and relevant skills in CAD, CAM, CMM and Industrial Robotics by:
a. Develop curricula to include skills in the above areas relevant to current industry needs.
b. Enhance the existing laboratories in these areas at UTRGV to include state-of-the-art, hands-on training experiences and support the course changes.
2. Provide "stand-alone" programs to train and certify students from other institutions, industry representatives, and displaced workers.

Resources and Infrastructure to meet the objectives

The Industrial Robotics lab at UTRGV has FANUC Collaborative Robot CR-7*i*A/L with vision system**.** The FANUC Robotics Certified Education Robot Training (CERT) Program promotes understanding of FANUC Robotics' Automation solutions through the development and implementation of integrated classroom instruction and student projects. The robotics laboratory at UTRGV has the latest FANUC Collaborative robot with vision system. The faculty are certified instructors to offer variety of FANUC certificates. The ET program at UTRGV is a Certified Training and Education Site for FANUC Robotics Material Handling Program Software and iR-Vision 2D (15).

The CAD lab at UTRGV has SIEMENS NX Product Life Cycle Management software bundle that serves as the principle CAD software that is employed throughout the engineering technology curriculum. NX CAD Design Certification is perfect for students and educators who want to demonstrate core design skills in NX. The certification is achieved through an online exam that tests skills and knowledge of the NX software. NX Certification enhances the competitive edge and reputation of both students and schools and provides an industry recognized credential that both students and educators can use to advance their careers (16).

The CNC lab at UTRGV has recently acquired a new-generation FANUC ROBODRILL α-D*i*B Series Vertical Machining Center. The Five-Axis ROBODRILL has high-speed tool changer that can carry 21 tools and offers the best reliability in its class. With a tool change time of 0.7 seconds and a turret capable of handling tools weighing 4 kg, the new advanced version is both the fastest and strongest vertical machining center on the market. Using intelligent cutting strategies, ROBODRILL achieves the same results as more powerful machines in less time, regardless of whether the application involves high-speed machining, mold making or 5-axis machining. This machine serves as the best training tool to prepare students for Level I & II *National Institute for Metalworking Skills* (NIMS) Certifications (17).

Credentialing

NIMS is a nationally recognized validator of performance through practical experiences that reflect the manufacturing industry. It provides excellent, industry-developed and validated standards, credentials, and training frameworks that enable collaboration between educators, industry, policy makers and community-based organizations to increase the performance of manufacturing workforce. NIMS was formed in 1995 to develop and maintain a globally

competitive American workforce and is the industry standard for training and skill validation within precision manufacturing. NIMS credentials are earned by students, trainees, apprentices, employees, and military personnel nationwide and around the world. By earning NIMS credentials, these individuals secure a competitive edge when applying for jobs because they have demonstrated that their skills meet the industry established standards. And NIMS credentials never expire. (18,19)

The Quality Control and Metrology lab at UTRGV has the state of the art Hexagon Global Performance Bridge CMM (20). Two of the Engineering Technology instructors (authors) are trained by the Applications Engineers and PC-DMIS Trainers who are all factory trained to the very latest standard to take advantage of all the software and hardware advancements made. These trainers are using, testing and being trained in the software before it is released to market; this means they have more experience than third party suppliers which will reduce costly mistakes due to inexperience. Therefore, the faculty engaged in training students in the latest CMM machine and PC-DMS software are fully trained and possess the skills required to handle this advanced training. This aspect of the training program is very much appreciated by the partnering industries (21,22).

Embedded Certification Curriculum Development

The core components of Engineering technology curriculum at UTRGV builds on the marketable skillsets imparted to students in Industrial Robotics and Automation, CAD/CAM, and Coordinate Metrology (Quality Control). The development and dissemination of industry recognized certifications as part of the regular curriculum will greatly enhance the marketability of engineering technology students successfully graduating from this program for the benefit of the targeted industries in advanced manufacturing.

The following four certifications are implemented at the UTRGV's Engineering Technology program:

Certification 1: Fanuc Handling Tool Operation and Programming *(Lab component of Robotics- a core course of the ET program)*

Certification 2: SIEMENS NX Design *(Lab component of the Design Graphics II- a core course of the ET program)*

Certification 3: NIMS CNC Certification *(Lab component of the Computer Numerical Control- a core course of the ET program)*

Certification 4: HEXAGON PC-DMS Dimensional Metrology Certification. *(Offered separately and not part of the regular curriculum, as a supplement lab component, of the Quality Control - a core course of the ET program)*

The above four certificates are developed to be offered as a part of the courses in the core curriculum as shown in the above parentheses. This will save students the time and cost in acquiring these certificates outside of their Bachelor of Engineering Technology degree program. The corresponding courses with embedded certifications are shown in the Figure 1.

❖ **Course I: Robotics** (3 cr Hrs, 2 Lec, 3 Lab) with industrial certificate.	➢ **Fanuc Handling Tool Operation and Programming**
❖ **Course II: Design Graphics II** (3 cr Hrs., 2 Lec, 3 Lab) with industrial certificate.	➢ **SIEMENS NX Design**
❖ **Course III: CNC** (3 cr Hrs., 2 Lec, 3 Lab) with industrial certificate.	➢ **NIMS CNC Certifications**
❖ **Course IV: Quality Control** (3 cr Hrs., 2 Lec, 3 lab) with an option to enroll in a supplemental lab to acquire industrial certificate.	➢ **HEXAGON PC-DMS Dimensional Metrology Certification.**

Figure 1: Embedded Certification Curriculum Development

Modes of Certificates Adaptation

The Robotics track currently offers certification in Fanuc Handling Tool Operation and Programming as part of the regular curriculum as a laboratory component. It is proposed to enlarge the pool of certifications in this track that can be offered to students, veterans and industry personnel to enrich their skills in this field.

These are the other three certifications that are planning to be offered during the convenient times for the participants under the Robotics track:

Certification 1: Robot Operations
Certification 2: Robotic iRVision 2D Course
Certification 3: Robo Guide—Robotic Work Cell

The Design Graphics track currently offers SIEMENS CAD certification as part of the curriculum during the regular curriculum as a laboratory component. This track has the potential to include SIEMENS CAM-Manufacturing certification outside the curriculum that can be offered to students.

The following additional certification is proposed to be offers under the Design Graphics track:

Certification 1: SIEMENS CAM- Manufacturing

The CNC track currently offers NIMS CNC Level 1 certificate to students as part of the regular curriculum through the laboratory component and this can be enlarged with the addition of NIMS CNC Level II certificate offered outside the regular curriculum. These certificates can be offered to students, veterans and industry personnel outside the curriculum in the evenings.

The following additional certification is proposed to be offered under the CNC track:

Certification 1: NIMS CNC Level II

The Quality Control track currently offers HEXAGON PC DMS Dimensional Metrology certification outside of the regular curriculum as a stand-alone course. This will require that the students spend additional 40 hours of specific theory and practice outside class time in PC-DMIS programming and CMM operation. The Metrology course in which this certificate is embedded will provide the foundations of dimensional metrology and coordinate measurement.
It is proposed to add two additional certifications for the students, veterans and industry personnel in this track.

Certification 1: Coordinate Measuring Machine Operation and Maintenance
Certification 2: Geometric Dimensioning and Telerancing (GD&T)

The above discussed certifications in the key areas of advanced manufacturing will attract prospective students, industry personnel, veterans including the unemployed workers who want to re-tool their skills, and students from other universities and colleges without a certification program. The revenue generated through these certification programs will serve as a funding source to continually enhance and update the equipment in the labs that anchor these certifications. The Figure 2 presents the training curriculum for the industry sponsored certification programs. These curricula are primarily developed by the corresponding industries and they train the instructors to serve as the master trainers that are capable of providing the standardized trainings to the prospective students and attest their skills for the eligibility to earn certifications in the corresponding technical areas. The duration and mode of the certification trainings are recommended by the corresponding industries that offer these certificates in their own facilities, as well as authorize other higher learning institutions to award such certificates.

❖ **Robotics Track**	➢ **Certification 1: Robot Operations** **16 hours:** **8 theory** **8 labs**
	➢ **Certification 2: Robotic iRVision 2D Course** **32 hours:** **16 theory** **16 labs**

	➢ **Certification 3: ROBOGUIDE: Robotic Work Cell** **8 hours: theory/lab**
❖ **Design Graphics Track**	➢ **Certification 1: SIEMENS CAM-Manufacturing** **16 hours:** **8 theory** **8 labs**
❖ **CNC Track**	➢ **Certification 1: NIMS CNC Level II** **32 hours:** **16 theory** **16 labs**
❖ **Quality Control Track**	➢ **Certification 1: Coordinate Measuring Machine Operation and Maintenance**
	➢ **Certification 2: Geometric Dimensioning and Telerancing (GD&T)**

Figure 2: Training curriculum for industry certification program.

The state of the art labs in robotics, CAD/CAM and automation with industry approved curriculum will attract more students to the engineering technology program that lays an emphasis on hands-on training. To build highly effective and self-sustaining programs with broad impacts in advanced manufacturing will require innovative approach in managing resources available to programs within the university's challenging budget requirements.

Project Planning and Implementation Strategy

UTRGV consulted industry to determine employer demand for skilled training in targeted industries and occupations. After identifying gaps in existing education and career training programs and reviewing other programs, this project's strategies relied heavily on the National Association of Manufacturers (NAM) and were leveraged by UTRGV to accomplish the following: 1) completely modernize the college's Engineering technology merging it into a Modern Manufacturing Technology and with the college's credential-based, technology-enabled, short-term training programs; latticing and stacking industry-recognized credentials (NIMS, Siemens, FANUC, Hexagon Intelligence); uplifting ET instructors' abilities to use advanced technology and contextualize soft skills and manufacturing concepts into their teaching; and requiring all students to achieve a certification based credentials validated by industries.

Engaging modern manufacturers and industry partners in program design based on advanced manufacturing skills required by students to win gainful employment in the current competitive labor market through a new oversight and advisory council.

The interactions with the advisory council resulted in the following three strategies to be implemented by UTRGV:

Strategy 1: Build the Engineering Technology Program that Meet Industry Needs

Strategy 2: Enhance Career Pathways Options for Students and Industry Personnel

Strategy 3: Accelerate and Improve Certification in Advanced Manufacturing to enhance Employment Attainment of Graduating Students, Veterans and Industry Personnel seeking reemployment.

Program Evaluation Questions:

Questions utilized in evaluating the program included the following:

- Is the program on target in accomplishing the goals?
- Were strategies implemented as planned?
- Are there obstacles that have arisen during the deployment of strategies?
- Are the expected outcomes being produced?
- Are there unintended consequences?

The evaluation steps taken by the UTRGV to create and run the industrial certifications are work in progress and the relevant data will be collected and analyzed in due course. The assessment of the operational strengths and weaknesses of the program after a complete implementation will be conducted. To assess the effectiveness of implementation strategies and timeliness of meeting targeted tasks, the following sources will be utilized:

- Interviews with students, and instructional faculty
- Feedback from the Industry partners

Conclusion

The primary outcome of the project implemented at UTRGV is to equip ET students with industry recognized certifications approved by primary certifying entities such as NIMS, FANUC, SIEMENS, and Hexagon Manufacturing Intelligence to face the challenges of 21st century manufacturing industry. The overall goal of the project is to help meet the nation's forthcoming need for highly trained technicians/technologists for Industry 4.0. Strategies include developing, curriculum and laboratory resources, to establish certifications in the core areas of advanced manufacturing. There is significant demand from industry for well-prepared workforce capable of working in the advanced manufacturing industries with skill sets in robotics, CAD, CNC and CMM. As a result, the goal is to develop curricula that has embedded certifications and associated tools that can address current and future industry expectations. The certificates will also be offered to students at other institutions and to workers in industry to broaden impact. The curricula covering these certificates will serve the students enrolled in the engineering

technology program as well as the industry personnel to retool their skills in advanced manufacturing. The certificates are designed to provide significant hands-on training in robotics, CAD/CAM and CMM-Dimensional Metrology and impart skills that are very critical to current industry needs. As a result of the program, engineering technologists will enter the workforce prepared to adapt to the complex and changing demands of Industry 4.0. In addition, this project will help bridge the gap between academia and industry. These bridges are critical for providing new resources to recruit and strengthen the well-trained pipeline of graduates in engineering technology.

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