AC 2011-951: MODULAR CURRICULUM DEVELOPMENT FOR MECHATRONICS TECHNICIANS

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Modular Curriculum Development for Mechatronics Technicians

Abstract

The paper describes a modular curriculum development project created by Purdue University Calumet (PUC) in the Mechatronics Engineering Technology field. In partnership with Ivy Tech Community College (ITCC) and College of DuPage (COD), PUC is developing thirty instructional modules in the Mechatronics area. In response to industry demand for multifunctional engineering technicians, Purdue University Calumet has developed an innovative Mechatronics Engineering Technology baccalaureate program that combines mechanical, electrical, electronic, and computer engineering technology skills. This paper gives details about the three-year effort on curriculum development and implementation project. The goal of the project is to develop and integrate curriculum and instructional materials based on an interdisciplinary, project-centered, collaborative learning approach to instruction and restructuring an engineering technology program. The module development is based on the revision of existing courses to serve the changing needs of educational and industrial partners as well as other constituents. This paper describes the mapping of the modules to existing courses in the associate degree plans of study in partnership institutions, which allow students who complete the modules to receive course credits toward associate-level degrees in the participating institutions at the same time. Modular offerings will allow certification at beginner, intermediate, and advanced levels in Mechatronics that meets industry workforce needs, while it facilitates receiving an associate degree. This approach enables a seamless transfer for students between colleges and university partners. A complementary aspect of this modular development is also the incorporation of innovative interactive and online delivery of lecture and laboratory materials to accommodate a flexible schedule, integration of experiential learning, and collaboration with industry. Results in regards to these goals, as well as the assessment and continuous improvement efforts of the project and its progress, will also be addressed in this work.

Introduction

A recent survey by the National Association of Manufacturers[1] shows that a large number of United States manufacturers continue to experience a serious shortage of qualified employees. There is a large gap between student preparedness and employment opportunities in the manufacturing industry. This paper describes the effort between three institutions of higher learning to close this gap by adapting its mechatronics technician curriculum[2] and forming the partnerships with regional industry.

Adapting the curriculum by modularization enables students to acquire necessary skills and competencies in the most efficient and effective manner. Forming partnerships with industry provides the students with a seamless pathway to industry and the needed experiential learning component in their portfolio. The combined effect of meaningful, modular, project-based education, along with practical experience, gives students the opportunity for completion of the educational objectives, provides the best employment opportunities, and prepares them as ready-to-work employees for regional industry. In the next sections, a summary of the curriculum modularization efforts, along with experiential project-based learning and innovative delivery methods, will be presented.

Modularization and Sequencing of Mechatronics Curriculum

The necessity for multi-disciplinary programs, reflecting the industry need for graduates who can be multi-task-oriented and understand the whole system, is increasing as technology improves. Industrial multi-disciplinary skill training programs can be viewed as high-quality, technical teaching programs, particularly when they are supervised and/or taught by an institution of higher education[3]. To serve this need, Purdue University Calumet with the tremendous support of industry, in particular the packaging industry, developed the Engineering Technology baccalaureate program in Mechatronics Engineering Technology.

Purdue University Calumet (PUC) leads this project which will help meet the growing need of manufacturing and technology-based industries for technicians and engineering technologists that are familiar with electro-mechanical systems. PUC and two area community colleges, Ivy Tech Community College (ITCC) and College of DuPage (COD), have been partnering with such industries in a number of projects helping them with their apprenticeship training programs for multi-skilled (electrical & mechanical) employees. The primary goal of the project is to address the need to close the existing knowledge gap by providing the high-tech multi-skill next generation workforce needed for regional industry by developing materials, which are modular and flexible enough to be customized. These materials will serve the changing needs of educational and industrial partners. Three tiers of course modules are being developed for two-year college freshmen and sophomores and industry professionals. Existing electrical and mechanical engineering technology courses are augmented and reorganized into thirty enhanced modules. Completion of all modules at each level will allow students to receive a certificate of completion. (See Table 1, as an example).

To ensure the success of the modular curriculum, the mapping of modules to existing college courses at three institutions was done. For example, a student that completes module 1-1 and 1-2 will receive the ITCC course credit for INDT 113 (equivalent to 2 modules). The same student completing additional modules, say 1-3 and 1-4 will receive PUC credit for EET 214 (equivalent to 4 modules). As the modules are developed during the project period, curriculum processes are being completed at each institution to formalize course equivalencies with the modules in coordination with the office of the registrar and records. PUC, ITCC, and COD will sign articulation agreements for automatically establishing transfer credit for the completion of the required modules that comprise the completion of a course. The registrar office will then post the course credit on the transcript. Currently, each institution has processes to give college credits to students who obtained knowledge gained through non–traditional means where:

- ITCC has an established process called Prior Learning Assessment (PAL) to grant college credits to students who gained knowledge in a non-traditional method (e.g., work experience).
- COD has the Credit by Demonstrated Competence program, which offers the opportunity to demonstrate achievement outside the classroom and gain college credit for it. Credit can also be earned by Credit by National Examination.

- At PUC, once a student is admitted to the Mechatronics Engineering Technology program, the academic department can provide a report of departmental credit to the Registrar. Accordingly, the Registrar will post course credits on the student's transcript. The faculty members assign the departmental credits after careful evaluation and comparisons of the learning outcomes pertaining to equivalent courses.
- PUC has already established an articulation agreement with ITCC for some of its technology programs; however, the articulation agreement for the Mechatronics Engineering Technology program at the associate degree level will be established among three institutions during this project period.

Table 1. Beginner's Level Modules

Mod.	Module Title	Contact *hours*		Responsibility			Location & Delivery Method	
		Lect. %	Lab %	Institution	Faculty	The modules to be developed from the following existing courses at PUC/ITCC/COD	Lecture	Lab
1-1	DC Electrical Systems	50	50	ITCC	Instructor 1	**PUC**: ECET 214 **ITCC:** EECT 111, EECT 121, EECT 122 EECT 127, INDT 113 **COD:** ET1100, ET1101, ET1141, ET1151, ET1152	ITCC In-class/distance	ITCC In-class
1-2	AC Electrical Systems	50	50	ITCC	Instructor 1		ITCC In-class/distance	ITCC In-class
1-3	Analog Electronics	50	50	COD	Instructor 2		COD In-class/distance	COD In-class
1-4	Digital Electronics	50	50	COD	Instructor 2		COD In-class/distance	COD In-class
1-5	Fundamentals of Hydraulics and Pneumatics	60	40	ITCC	Instructor 3	**PUC:** MET 230 **ITCC:** INDT 104, INDT 201	ITCC In-class/distance	ITCC In-class
1-6	Fluid Circuits w/o Elec. Control	50	50	ITCC	Instructor 3		ITCC In-class/distance	ITCC In-class
1-7	Introduction to Mechanics I	100	0	ITCC	Instructor 4	**PUC:** MET 118 **ITCC:** DESN 221	ITCC In-class/distance	N/A
1-8	CAD	30	70	COD	Instructor 5	**PUC:** MET 100 **ITCC:** DESN 103, INDT 102	COD In-class/distance	COD In-class
1-9	Blue Print Reading (Elect & Mech)	40	60	COD	Instructor 5		COD In-class/distance	COD In-class
Internships (Experiential Learning), 8-hours/day		0	100	ITCC	Instructor 6		N/A	ITCC In-class

The project sustainability is secured by providing students with a clear career path through mutually articulated and recognizable certificates, associate degrees, and four-year degree programs offered in participating institutions. Once an individual completes the modules he/she will receive credits for existing courses (in their respective participating institution) leading to certification and degrees. Individuals from the industry can also take specific modules to develop skills in a particular area for career advancement. In addition, the institution's advisory boards, which include all constituencies, along with an external evaluator, are used as an evaluation tool for continuous improvement. They also provide input toward the development of modules. This board includes membership from faculty of partnering institutions, industry partners that have committed to internships and experiential learning, and other regional companies that are deemed to benefit from this project.

Curriculum Modularization Example

From Table 1 we can see module titles and corresponding courses belonging to partnering institutions. For example, COD's course ELECT 1100 (Introduction to Electricity) is equivalent to the first three modules of the modified curriculum. Table 2 shows the course and module comparison outline. Each module is delivered using synchronous distance delivery of a laboratory-based course with Polycom® Audiovisual Technology System. This means that students are able to follow the lecture from all three campuses interactively, listening and asking questions, while the instructor is delivering from one of the sites. After the lecture portion, the practical portion is performed on each campus under the supervision of the instructor or qualified staff in the laboratory. A learning management system such as Blackboard® is used to complement the class lectures, administer exams, and communicate with an instructor in and outside of the designated time. Table 2 outlines the modular contents as it relates to regular courses. Assessment as a part of the continuous improvement process has also been utilized.

Table 2: Course and Module Comparison Example

Module Title	Corresponding Course Name	Content	Module Objectives	Assessment Questionnaire
1 – DC Electronics	ITCC-EECT 111 Introduction to Circuit Analysis COD-ELECT 1100 Introduction to Electricity and Electronics	1. Basic Concepts of Electricity Atomic Structure 2. Electrical Quantities and Ohm's Law 3. Measuring Instruments, Electrical Safety, Measuring LAB 4. Resistors and Wiring & Conductors 5. Electrical Symbols and Series Circuits 6. Parallel Circuits 7. Combination Circuits & Kirchhoff's Laws	1. Define and use concepts, terms, & laws important for DC electrical systems 2. Understanding of current as the rate of flow of charge. Solve Ohm's law problems. 3. Use exponents, scientific notation, and engineering and prefix notation 4. Be able to calculate the voltage, resistance and amperage in a series, parallel, and combination circuits 5. Solve for power in DC electrical circuits	Objectives of this module are: 1. Define and use concepts, terms, & laws 2. Set up and solve problems involving current, voltage and resistance. 3. Solve for power 4. Use exponents, scientific notation, and engineering and prefix notation. 5. To understand and recognize faults in series and parallel circuits. 6. As a result of this course my ability to apply current knowledge and adapt to emerging applications of mathematics, science, engineering, and technology can be rated. How well did this course meet this objective?

Table 2 shows the correspondence between courses and Module 1, called DC Electronics. The difference is in the delivery of the content using online method and anytime remote access. Modularization allows for flexible learning and effectiveness of the curriculum where students pursue only modules, which they require, rather than the entire course. This approach is very helpful for students with diverse and experiential proficiency permitting them to complete their studies with minimum redundancy. The other beneficial aspect of the education is the transparency of the curriculum among the partners and ability for students to be awarded for the effort while pursuing several degrees concurrently. This is not the case in the traditional educational models where student completes the educational goals sequentially. Furthermore, some of the modules will be based on the projects from industry improving the experiential learning component and relevancy of their educational objectives.

Experiential Learning Curriculum

One of the project goals is to incorporate experiential learning in each module level so that the modules are meaningful, practical, and interesting to students and professionals. A number of experiential learning/internship industry partners have committed opportunities for the participants: 10 in year 1, 15 in year 2, and 20 in year 3 of the project. Furthermore, in at least fifty percent of the developed modules, industry-based projects developed between faculty and industry expert advisors will be included.

Experiential Learning, (EXL) will follow the activities to ensure the 8 National Society of Experiential Education (NSEE) standards. These standards are: intention, preparedness and planning, authenticity, reflection, orientation and training, monitoring, assessment and evaluation, and acknowledgement. The participants will be evaluated to determine if they are academically prepared for EXL by their academic background. The faculty and employer, through prior agreement on learning objectives, will control the quality of the experience. Experiential learning will require a final paper and exit interview with the faculty and employer, and the final survey will be conducted to provide reflection opportunities on the experience. The participants will meet with the faculty and employer before the EXL starts to agree on learning objectives and orientation will occur at this time. The participants will be required to send weekly progress reports to the employer and the faculty who will monitor each participant’s progress. The employer and faculty will grade the final report by the participants. Finally, an exit interview and recognition event with student, employer, and faculty will be arranged.

A survey of students will be performed to determine learning outcomes, learning environment, and participant’s satisfaction in experiential learning/internship. Employers will be surveyed at the end of each experiential learning/internship period for the purpose of determining level of expectation, satisfaction, and professionalism of interns.

Innovative Delivery

Three methods of delivery of course and laboratory materials are used[4]. 1) Synchronous Distance Delivery (SDD). 2) Asynchronous online delivery, and 3) Twenty-four/seven remote access to software tools, lecture notes, assignments (laboratories and homework) from anywhere, anytime and on any platform.

Twenty-four/seven operation refers to student access to software tools needed to complete all course-related work, such as simulation, programming, and report writing while the actual labs are taught remotely using the Polycom® technology. Polycom® technology, coupled with the other related technology allows real-time synchronous delivery of laboratories at remote locations. Each institution, ITC, COD and PUC already have the technical support (technicians) for remote delivery of the laboratory-based courses. The technicians are being utilized to provide support during the remote instruction of the laboratories. For example, currently, PUC offers laboratory-based courses to its remote campus 17 miles away and technical support is provided at both locations. Each institution has already invested in both human resources and relevant technology for remote delivery of laboratory-based courses. The existing full-time technician positions coupled with institutions continuous support for technology upgrade will help sustain the proposed project beyond the project period.

In Synchronous Distance Delivery, a student experience can be similar to a live classroom, listening to the instructor, asking questions, and observing the instructor's computer screen. Asynchronous distance delivery mode involves video streaming and DVD-based delivery, and online delivery of lecture and laboratory. For a laboratory-based engineering technology course, PUC has already implemented the following technologies for synchronous distance delivery: Polycom® Audiovisual Technology System, Virtual Network Computing (VNC), 24/7 Server System, Virtual Laboratory facility, and Multi-modal Synchronous classroom with two-way audio/video conferencing capabilities.[4] Polycom® uses video-over-IP (TCP/IP-based audio/video conferencing) that connects two or more sites over high-speed internet connection. A typical setup includes a microphone, a camera and a display unit for video interface. With VCN technology, a student can see the instructor's computer screen at a remote location. This project also uses the above-mentioned technologies. COD has two classrooms fully equipped with Polycom® technology. Each classroom is set with three 52" monitors and a pull-down projector-screen. In addition, one mobile Polycom® system is also available for audio/video conferencing.

The 24/7 Virtual Laboratory allows students to login and use commercial grade software tools to perform his/her assignments anytime from a distance location. These commercial grade software tools such as: Allen-Bradley's RSLogix 5000, NI's LabVIEW, Elau's EPAS4, etc. are expensive to own by a student, yet can be accessed and used to their fullest extent from any computer with a high-speed internet connection. The twenty-four/seven server system allows the virtual laboratory to be available 24 hours a day, 7 days a week, and is also used by students located in the remote classroom during class and laboratory demonstration. Students sitting in live classroom do not need to use this facility while they are logged on to the local server at the live classroom location. Furthermore, course syllabi, assignments (homework, laboratory and other assignments), are all kept on a 24/7 computer server so that a student can retrieve and work on assignments twenty-four/seven via high speed internet connection.

PUC, Department of Engineering Technology has already purchased four such high capability server systems. Two of these are currently used for the 24/7 Virtual Laboratory facility and the other two will be available for Mechatronics-related laboratory software tools service. The Department of Engineering Technology also invested in two Polycom® systems for an off-site location of PUC, called the Academic Learning Center, located 17 miles from main campus at nearby location. The Department of Engineering Technology has recently established a new state-of-the-art Mechatronics Engineering Technology laboratory through gifts-in-kind totaling approximately $600,000, from industry partners. This laboratory will be available to ITC and COD students remotely and to PUC students locally.

Asynchronous distance delivery is an online delivery method where classroom lectures notes and other interactive materials, such as tests and assignments are available online 24/7. Enrolled students can access those materials and complete the assignments within a specified time. PUC, School of Technology has several courses that are currently asynchronously delivered online. For asynchronous delivery, the laboratory-based lecture and laboratory activities are captured on video, then saved on DVD's and later posted on the Web for streaming.

The program improvement lies in the idea of redesign of engineering technology courses and sequencing. Furthermore, hands-on activities are reinforced by field experiences. The Society of Manufacturing Engineers (SME), The Institute for Electrical and Electronics Engineers (IEEE), The American Society of Mechanical Engineers (ASME), and Accreditation Board for Engineering and Technology (ABET) is used to draw key competency areas. The three partnering institutions are using these criteria to guide their efforts in creation of the curriculum material.

Underrepresented Population

One of the focus areas of this project will be to target the underrepresented population (Hispanic, Asian, and African American) in the region. The project will involve between 50-60 participants in three years. The objective is to select the participants so that it represents both racial diversity and gender diversity. In this regard, ITCC, COD, and PUC do provide a larger pool of students from underrepresented population, mainly African American, Hispanic population and female students. The area high schools and industrial workforce in the region represents similar demography as well. Each institution pursues initiatives and specific strategies to attract and recruit students from the underrepresented population. Details on these strategies for each institution are provided below:

ITCC has a large and diverse population. Of more than 8,000 students, women comprise the majority of students (59%), Black and Hispanic (34%).
ITCC will continue to pursue the following strategies to attract underrepresented population for this project:

- Dual credit agreements with two area high schools districts, predominantly African American and Hispanic population respectively.
- Participates in workshops with middle schools and also involvement with several community organizations by participating in their resource fairs.
- Partnerships where ITCC provides information and initiates the admissions process for displaced Indiana workers.
- Support community groups that advocate education for specific ethnic and gender specific populations.

COD has a large and diverse population. Of more than 28,000 students, women comprise the majority of students (55%), Black (6%) and Hispanic (14%). Over half of degree-seeking students are estimated to be first generation. There are a large number of economically disadvantaged students, and COD represents the only affordable institution of higher education in the area for many of them. Mechatronics technology program is working with community development office and its specialist to promote and recruit students from under-represented groups for the grant. The role of Community Development office is to establish and support internal and external partnerships. COD continues to pursue the following strategies to attract underrepresented population for this project:

- Mechatronics program (called Integrated Engineering Technology, InET at COD) uses community development office pathfinder initiative designed to guide African-American and Latino high school juniors in an exploration of high-wage, high-tech career possibilities as they acquire leadership skills and experience. It features a week-long course taught by COD faculty and provides linkages to established community programs to enhance student achievement and success.
- College of DuPage with Office of High School Partnerships also works through workshops and seminars with regional high school technology center TCD, specifically focused on mechatronics program, to recruit students from under-represented groups. Five course dual credit certificates have been established to recruit students for the program. After acquiring a certificate students are able to transfer to the InET program at COD.
- InET program is creating a video clip with collaboration with COD multimedia services through monthly news magazine program called *Images* to promote program to under-represented groups.

Currently, 33% of 10,000 PUC students are from an underrepresented population and 57% of all students are female. PUC will continue to pursue the following strategies to attract underrepresented population for this project:

- Partner with the local school system's Project Lead the Way (PLTW) programs. PUC currently has 42 high school freshman/sophomore students meeting daily in CAD labs to take PLTW courses. Of these, 14 men, 28 women (67%), 8 African American (19%), 9 Hispanic (21%) and 1 mixed race (2%). PUC has been offering PLTW courses for the past five years.

- Dual-credit agreements with area high schools to support students' transition into the technologies-related degree programs. Area high schools have 100 of their 800 students taking PLTW courses. So far over 50 first generation students have gone on to engineering/engineering technology majors at various universities after completing the PLTW program.

- PUC faculty/staff provide hands-on technology demonstrations to area high school/middle school students by bringing them on campus.

- A "Tech Mobile" (mobile engineering technology demonstration station) is being developed to visit area schools and provide hands-on experience with Mechatronics.

Many students leave college to pursue the reward of immediate income-producing employment, forgoing the long-term gains of higher education. Also, many of these students encounter family pressures to go to work. For the first generation college students, and to increase the retention rate, there needs to be explicit rewards over and beyond those of learning for its own sake. We see a need for a program that presents an opportunity for both career-enhancing work and education. The project with experiential learning experience, and certificate of completion at the beginner, intermediate, and advanced levels will present such a reward.

Fields such as electro-mechanical, manufacturing, and Mechatronics are often perceived as unappealing, and the reality of today's manufacturing environment is a surprise to students who encounter it in field experiences. They are amazed at the clean, technology-driven environments. "Student support" can mean, among other things, providing students with these first-hand experiences, as they cannot easily walk in off the street and experience them on their own. Contemporary engineering/manufacturing technology education also demands that instructors interact with local industry and government to know what resources are available, and to remain current as their field evolves. This project provides and facilitates such opportunities.

Summary

This partnership project between PUC, ITCC, and COD provides a modular curriculum for students interested in obtaining the two and four year degrees and work in the field of Mechatronics. Having innovative delivery methods, seamless transfer opportunities, and incorporating experiential learning components with local industry, students are able to accomplish student educational objectives in a most efficient and effective manner.

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