Meeting Rural Industry Needs with Mechatronics and Stacked Credentials

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Introduction

The Upper Peninsula of Michigan (UP) is a beautiful area with abundant outdoor recreational opportunities and majestic natural scenery, but its low population density creates numerous challenges relating to the alignment of needs between educational institutions and industry. Geographically, the UP totals 16,538 square miles, making it slightly larger than Massachusetts, Connecticut, Delaware, and Rhode Island combined[1]. With a population of only about 300,000 people, however, the UP represents 29% of Michigan's total land area, but just 3.3% of its population[2]. The local economy is primarily comprised of small businesses of under 200 employees, if not much fewer, and there are only two public community colleges and three public universities serving this entire region. The extremely rural nature of this area certainly adds to its natural beauty, but also creates geographical and economic difficulties in aligning educational opportunities with the needs of industry.

Bay de Noc Community College, colloquially known simply as Bay College, is one of the two public community colleges to serve this area. Its centralized location makes it a primary talent pipeline for a large portion of UP businesses, while its wide range of occupational and transfer programs make it a destination of choice for area students. The college has also received national recognition for its success with the Achieving the Dream (ATD) grant by being named an ATD Leader College, as well as for its work in developing entire degree pathways using nothing but open educational resources[3,4]. To ensure it is offering the most relevant and up-to-date curriculum and non-credit training opportunities, college personnel work closely with area business leaders to learn about their employee skill requirements and to develop mutually beneficial educational opportunities.

Despite this repeated success in implementing educational improvement initiatives, however, the college discovered in 2013 that they had a problem in their ability to meet employer demands within the local manufacturing sector. Whereas one employer needed one or two people with electrical skills, another employer needed one or two people with knowledge of fluid power systems. Still others needed blueprint reading, machine tool skills, knowledge of industrial motors, understanding of process control techniques, robotics and automation abilities, or a wide variety of other skill sets. Given that Bay College supports a student population of only about 1,700 during the typical fall semester and has a similarly limited set of financial resources available, creating a separate academic program to address each of these skill sets was impossible. For years these employer demands had gone unmet, so something had to be done.

A solution began to present itself when the Dean for Business and Technology, Mark Kinney, traveled to Houghton, MI and met with Aleksandr Sergeyev, Associate Professor of Electrical Engineering Technology (EET) at Michigan Technological University. While Sergeyev provided a tour of the EET lab, he described a grant opportunity through the National Science Foundation (NSF) that might allow Bay College to not only obtain much of the equipment they would need to create the necessary academic program, but that could also be used to create a partnership between the two schools that would lead to coordinated curriculum and an articulation agreement between Bay College's program and that of Michigan Tech University. This proposed endeavor was ultimately successful, and the two institutions have since partnered on additional grants and projects that have shown tremendous early promise towards addressing the needs of the local manufacturing sector. The remainder of this paper describes this partnership, the educational opportunities that are now available, the early results of their work, and some lessons learned that are important for other institutions to consider when attempting to replicate such a partnership.

Overview of the Program

Bay College and Michigan Tech successfully collaborated on a grant proposal to the NSF for their Advanced Technological Education (ATE) grant, which was awarded for a total project cost of $702,324. Much of these expenses were dedicated towards personnel costs to develop robotic simulation software, create curriculum, and design the articulation agreement between the two institutions. Money was also reserved for stipends to be paid to workshop participants, travel to conferences and meetings, and instructor professional development. In order to truly align the curriculum, however, Bay College needed to purchase several robotic arms for instructional purposes. Therefore, just over $100,000 was reserved for the purchase of three FANUC LR Mate 200iD robots, with approximately another $25,000 for add-on options like battery packages and pill sorting packages. While the college was waiting for a response on its ATE application, however, another grant opportunity presented itself in the form of the Michigan Community College Skilled Trades Equipment Program (CCSTEP). Not knowing if the ATE grant would be approved or not, Bay College also decided to include a similar amount of funding within its application for this grant, which was also subsequently funded. Therefore, Bay College was able to purchase a total of six robotic arms, providing it with plenty of capacity to offer an advanced robotics curriculum that aligned with that of its university partner.

Even with grant funding, creating separate academic programs to meet each of the diverse requests from area employers was impractical. Instead, Bay College and Michigan Tech University aimed to create a single program that contained elements of each employer request. For example, rather than creating an entire program surrounding the need for graduates with an electronics skillset, and yet another program focusing on hydraulics and pneumatics, a single program would be created that included introductory coursework in each of these areas and that allowed students to customize the remainder of their educational experience to the specific industry or employer they wanted to target. Under this stackable credentials model, students are provided with multiple exit and re-entry points, allowing them to earn credentials and enter the workforce as they desire. For example, students can choose to earn a single certificate and enter the workforce, or they may stack an associate's degree on top of the certificate and then obtain employment in a position requiring this more advanced skillset. Furthermore, thanks to the articulation agreement developed between the schools, students can transfer their entire Bay

College experience to Michigan Tech University towards the pursuit of a bachelor's degree in EET.

In addition to giving students options for the level of education they desire to obtain, this model also works well for area employers. Those that are only looking for entry-level skills and are not paying a wage likely to attract full degree holders are able to draw from the pool of certificate earners. In the past, these employers were hiring individuals straight out of high school and providing them with on-the-job training for virtually every workplace skill they required. Under this model, the college is able to provide those entry-level skills in a variety of disciplines and the employer is able to more quickly on-board new employees. Those employers needing higher skill sets are able to draw from the associate's degree or bachelor's degree levels.

In addition to the development of academic programs under this collaborative project, several other educational options were also created. The first of these is to provide stand-alone, non-credit workshops to train and certify students from other colleges and universities, industry representatives, and displaced workers. Workshops have also been created to train educators at both the K-12 and postsecondary levels on the use of robotic arms and the role the field of robotics plays in science, technology, engineering, and math education. This activity is intended to broaden the scope of the project beyond just Bay College and Michigan Tech University. Through improving the quality of industrial robotics education at other area institutions via these trainings, the partnership should hopefully have a far-reaching effect on mechatronics and robotics education across the country. Furthermore, thanks to the attainment of certified education training in robotics by Sergeyev and Bay College's primary faculty member for the program, Mark Highum, Bay College and Michigan Tech University will also now be able to offer reciprocal certification opportunities to attendees of these events. This industry certification, provided by the robotics vendor FANUC, will help to create consistently high-quality robotics education programs and will stand as a symbol of such quality to employers looking for a program from which to draw new employees or train their existing workforce. Lastly, due to the difficulty of giving all students adequate time to practice programming real robotic arms, there was a recognized need for lifelike and portable simulation software. Thus, Scott Kuhl and the Computer Science department at Michigan Tech was brought in to develop such software. Titled RobotRun, this simulation software is now available through open source licensing to assist students and industry personnel in learning the basics of robotics programming.

Initial Results of Academic Programming

After meeting with area employers to assess their needs, as well as pulling together an advisory board of local experts, curriculum was developed for a mechatronics certificate program and submitted to the Bay College curriculum committee in the fall of 2014, which was then first offered to students during the Fall 2015 semester (Figure 1). Five students initially majored in the program, but several classes benefited from strong enrollment due to their inclusion in other degree programs on campus. This practice of including courses from the new major in other well-established degree programs on campus proved to be a valuable lesson learned that is recommended for other colleges looking to replicate this model. For example, Circuit Fundamentals I had a total of 17 students enrolled during its initial offering due to its inclusion as an option within the water resource management program. This benefit of including courses

Requirements – Min 24 credits

ELEC-130	Circuit Fundamentals I	4
ELEC-180	Electrical Machinery and Controls	4
ELEC-285	Fluid Power	4
XXXX-XXX	Approved Electives	12

Approved Electives

ELEC-145	Basic Process Control	4
ELEC -290	Introduction to Programmable Logic Controllers	4
MATH-102	Introduction to Technical Math	4
TECH-100	Basic Machine Tool Operation	4
TECH-101	Blueprint Reading	2
TECH-105	Materials of Industry	4
WELD-110	Introduction to Oxygen-Fuel Welding and Cutting	3
WELD-120	ARC Welding	4

Suggested Sequences Per Semester

		Cr / Ct
First Semester		
ELEC-130	Circuit Fundamentals I	4/4
ELEC-285	Fluid Power	4/4
XXXX-XXX	Elective	X/X
		12/12
Second Semester		
ELEC-180	Electrical Machinery and Controls	4/4
XXXX-XXX	Elective	X/X
XXXX-XXX	Elective	X/X
		12/12

Figure 1: Course Overview of the Mechatronics Certificate

within other degree programs was even more pronounced the following year, when two sections of Basic Process Control were required to support an enrollment of 37 students, again due to the course's inclusion in the water resource management program. The content of these new courses was also extremely beneficial to the students in the other programs, since, in the example of water resource management, process control and electrical skills had both been lacking by graduates in the past. The inclusion of these courses not only helped to address that knowledge and skills gap, but also boosted the enrollment in the new courses, providing legitimacy and indirect funding to the new program.

Another lesson learned during the startup of the mechatronics certificate was that the inclusion of electives provides students and employers hiring students or sending workers for additional training with the ability to tailor their studies to a specific industry or employer. During the first year of the certificate program, courses were mostly prescribed based on what the advisory board thought was needed in the industry. Those advisory board members recommended that Blueprint Reading be removed from the initial program proposal, since there were other skill sets that they thought would be more valuable. It quickly became apparent after meeting with other employers, however, that the skill of blueprint reading was actually a requirement in their industries, yet now it was no longer part of the mechatronics curriculum. Changes were therefore made to the certificate program to require only a basic list of courses, freeing up the rest of the program to be electives from an approved list (Figure 1 contains the complete list). Students can now target a specific industry or employer and choose the courses that are going to give them the greatest opportunity to obtain employment. One student may elect to take Blueprint Reading because their employer of choice requires it, while another one may focus instead on Basic Machine Tool Operation, since that skill is more desirable where they hope to work. This is another lesson learned during the first year of progress at Bay College. At the certificate level, where the total number of courses required is small, leave plenty of room for customization on the part of the student.

Given the initial success of the certificate program, and keeping with the ultimate vision for creating stackable credentials, curriculum was also developed for a Mechatronics and Robotic Systems associate's degree (Figure 2). Recent estimates by the International Federation of Robotics suggest that by 2019, more than 1.4 million new industrial robots will be installed in

General Education Requirements – Min 15 credits

		Cr
ENGL-101	Rhetoric & Composition	3
BUSN-177	Mathematics of Business -OR- MATH-105 -OR- MATH-107	3/4
XXXX/xxx	Social Behavioral Science\Humanities	3
XXXX-xxx	General Education Electives	5-6

Program Requirements (Minimum 32)

ELEC 130	Circuit Fundamentals I	4
ELEC 145	Basic Process Control	4
ELEC 180	Electrical Machinery and Controls	4
ELEC 240	Real Time Robotics Systems	4
ELEC 245	Robotic Vision Systems	4
ELEC 285	Fluid Power	4
ELEC 290	Introduction to Programmable Logic Controllers	4
ELEC 295	Mechatronics	4
XXXX/xxx	Approved Electives	13

Approved Elective (13 Credits)

CNSS 130	Introduction to Networks	4
CNSS 150	A plus Computer Maintenance	4
CNSS 220	Network Design	4
ELEC 135	Circuit Fundamentals II	4
ELEC 160	Electronics I	4
ELEC 170	Digital I Fundamentals	4
ELEC 272	Mechatronics Co-op Internship	1- 8
TECH 100	Basic Machine Tool Operation	4
TECH 101	Blueprint Reading	2
TECH 105	Materials of Industry	4
WELD 110	Intro to Oxygen-Fuel Welding and Cutting	4
WELD 120	Arc Welding	4
XXXX xxx	Any General Education Course	

Suggested Sequences Per Semester

		Cr / Ct
First Semester		
ENGL 101	Rhetoric & Composition	3/3
ELEC 130	Circuit Fundamentals I	4/4
ELEC 285	Fluid Power	4/4
XXXX xxx	Approved Electives	4/4
		15/15
Second Semester		
XXXX xxx	Approved Electives	4/4
ELEC 145	Basic Process Control	4/4
ELEC 180	Electrical Machinery and Controls	4/4
BUSN 177	Mathematics of Business Or- MATH 105 Or- MATH 107	3-4/3-4
		15/15
Third Semester		
ELEC 240	Real Time Robotics Systems	4/4
ELEC 290	Introduction to Programmable Logic Controllers	4/4
XXXX xxx	Social Behavioral Science or Humanities	3/3
XXXX xxx	General Education Elective	3/3
		14/14
Fourth Semester		
ELEC 245	Robotic Vision Systems	4/4
ELEC 295	Mechatronics	4/4
XXXX xxx	Approved Elective	5/5
XXXX xxx	General Education elective	3/3
		16/16

All Internships and Co-ops may require that the student pass a criminal background check.

Figure 2: Course Overview of the Mechatronics and Robotic Systems Associate Degree

factories around the world[5]. Furthermore, 2016 saw a 14% growth in new robot installations worldwide, with average global growth of 13% expected annually until 2019[5]. Meeting the educational needs of this growing industry was therefore a priority of the partnership, so grant funds were used to purchase a total of six robotic arms at Bay College, as well as a host of other trainers relating to programmable logic controllers, pneumatics, hydraulics, mechanical and electrical systems, and more. A vacant room on campus was converted into a lab space (Figure 3) and the equipment was installed. After successfully passing through Bay College's curriculum committee, the first associate's degree level courses were offered during the Fall 2016 semester. Thanks in part to the steps taken to build the Mechatronics certificate, a total of 13 students majored in the Mechatronics and Robotic Systems associate's degree during its second semester of operation. These students are in addition to another five who majored in the Mechatronics certificate, meaning a total of 18 students enrolled in the new degree program during just its first year of the associate's degree-level offering. Furthermore, three students graduated with the certificate during its first year of existence, with all three of them being retained in the associate's degree program during the 2016-17 academic year. Looking ahead to the Fall 2017 semester, four students are currently registered to enroll with the mechatronics

certificate as their major, with another 16 registered in the mechatronics and robotic systems associate's degree. This means that the program should realize its third consecutive year of growth.

Figure 3: Bay College's new Mechatronics and Robotics Lab

Initial Results of Non-Credit Workshops

Another significant aspect of this project was the development and offering of non-credit workshops. These workshops were designed to target three separate groups: industry personnel, other educators at both the postsecondary and K-12 levels, and K-12 students. During the first year of the NSF grant, a workshop aimed at other postsecondary educators was offered. A total of eight people attended this initial workshop, which was titled *Revamping Robotics Education to Meet 21st Century Workforce Needs*. The primary idea behind the workshop was that there is a significant need for industrial certification programs in robotics, since it is increasingly used across industry sectors to improve production throughputs while maintaining product quality. The benefits of robotics, however, depend upon workers with up-to-date knowledge and skills to maintain and use existing robots, enhance future technologies, and educate users. It is therefore critical that education efforts respond to the demand for robotics specialists by offering courses and professional certifications in robotics and automation. In an effort to help meet this need, the workshop introduced participants to new approaches for teaching industrial robotics to match industry needs and provide a replicable model for programs around the US.

The workshop had a maximum class size of 12 and offered a stipend of $500 to attendees to offset their time and travel, thanks to available grant funds. However, despite this incentive, several people either did not show up for the workshop or canceled at the last minute, bringing the final attendance count to just eight participants. It was therefore decided that a good practice might be to charge attendees a $200 deposit at the time of registration, to be returned to them with the additional $500 stipend once they successfully attend. This strategy was attempted when Bay College offered their first version of this workshop in December 2016. Unfortunately, attendance results were not improved. A total of just four participants made it to the workshop, despite a total of nine being registered. Incidentally, all five who dropped the course did so before paying the registration fee. When queried, reasons given for failing to attend included personal, professional, and travel-related issues. Those who did attend the workshop had positive comments, however. Since one primary motivator for faculty participation in professional development events is scheduling it at a time in which the faculty member is not obligated to their regular duties[6,7], and given the remote and wintery locale of Bay College, the upcoming year's strategy will be to hold the workshop during the spring or summer months.

The idea behind this approach is that potential registrants will be less busy and more likely to travel to the area when the weather is nice. Furthermore, crafting marketing efforts to demonstrate how attendance will directly impact attendees' teaching excellence could attract more participants, since this too has been shown to be a strong motivating factor in professional development participation.[6,7]

Another non-credit workshop with much better attendance success was that which was aimed at K-12 students. This workshop was held on a Friday and attendees were excused from their regularly scheduled high school classes. The class ran completely full at 12 participants. In order to recruit participants, area high school instructors from several local schools were asked to invite their best students to the workshop, ensuring that those in attendance stood to benefit from the curriculum and also served as strong possible future college students. At the workshop, participants learned basic principles of industrial robots, including topics on robotic safety, basic mechanics and controls, robotic frames, and programming architecture. Hands-on activities that were age- and skill-appropriate for high school students taught them the basic concepts of optimal robot programming and manipulation utilizing industrial robotics. Students were introduced to basic programming functions and taught how to optimize a robotic path to conduct a simulated industrial task. Utilizing the RobotRun simulation software developed under the grant, students were able to play games and conduct basic programming tasks to simulate the robotically controlled process. Again, feedback received was very positive and the day camp will be offered again next year to a new group of students.

RobotRun Software

Another aspect of the grant partnership between Bay College and Michigan Tech University is the development of robotics simulation software, titled RobotRun (Figure 4). This software has been fully developed and will be available for demonstration to conference attendees. The software simulates the programming and operation of a robotic arm, allowing students and industry personnel to craft programs and test them from the comfort of their home or office without taking up valuable time on an actual robot. Instructional lab exercises that have been co-developed by Bay College and Michigan Tech University faculty also provide practice opportunities for students that teach them about common programming mistakes and the proper technique to perform certain actions[8].

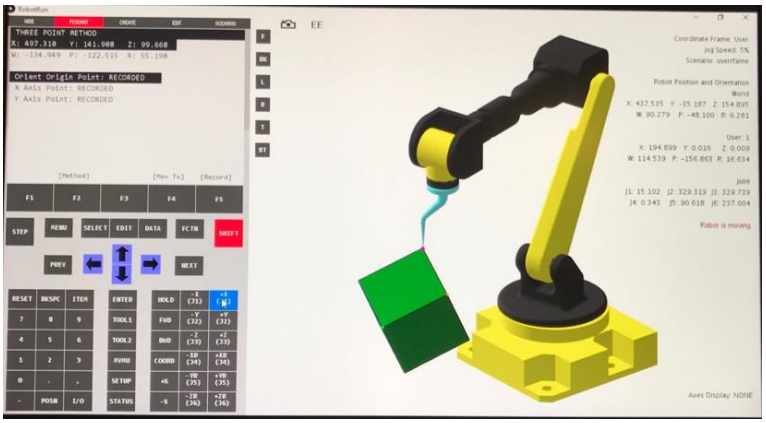

Figure 4: A screenshot of the RobotRun software

Other Developments and Lessons Learned

One of the most important steps taken at Bay College during the grant period was to send its primary faculty member to receive training and certification from Integrated Systems Technologies (IST). This training not only prepared him to teach the courses now offered at Bay

College, but also enables the institution to offer that same certification to its students and non-credit workshop participants. Given the limited number of locations available that offer this certification, the hope is that this training will pay off in the form of increased participation at workshop events in the future.

Another important lesson learned by the two partnering institutions this year was that all duties between the parties need to be clearly delineated and understood. While all grant deliverables were completed as planned, there was some confusion as to which specific pieces of curriculum were to be developed by Bay College and which pieces were to be developed by Michigan Tech University. This led to a certain amount of frustration and duplication of effort, so a meeting was scheduled at the beginning of year two to very clearly outline the expected deliverables of both parties before the year began. This seems simple, but has been an important takeaway of the development of this partnership thus far and is recommended for other institutions looking to form similar partnerships elsewhere. Partners should clearly state which curriculum will be developed by each party and supply deadlines for its completion. By taking the time to set up shared goals and ensure each partner fully understands the vision of what the partnership represents, the likelihood of partnership success is increased[9]. Ideally, the goals of the partnership should become the focus of each party, rather than the individual goals of the partnering institutions.[10]

Lastly, promoting the improvements made under this partnership has been an important aspect of the work and has helped to raise awareness of the benefits of the community college and university partnership, as well as the importance of education in the skilled trades. The governor of Michigan visited the Bay College campus to tour through the new mechatronics and robotic systems laboratory, among others, and even mentioned one of the college's programs that he visited during his State of the State speech. The director of the state's Talent Investment Agency also visited the campus and was thoroughly impressed by the opportunities the program makes available to students, stating an interest in additional partnerships in the future between the college and the agency. Taking advantage of opportunities to showcase the work being performed under the grant and partnership is another critical step for institutions looking to replicate this model.

Next Steps

Now that the academic curriculum and non-credit workshops have been developed, much of the work in the coming year will be aimed at increasing enrollment and more directly partnering with area industry. Already, several local manufacturers and the local job force board have contacted Bay College about employing their mechatronics and robotic systems graduates. With only a small number having completed the program in its first full year of operation, however, sufficient numbers have not yet been made ready for the workforce. Still, a manufacturing luncheon has been scheduled at Bay College's campus in the near future to further discuss with manufacturing representatives their needs for incoming workers and the ways in which this new model for stackable credentials can help them achieve their organizational objectives. With its third consecutive year of growth anticipated for 2017-18, this community college and university partnership based on industry needs is a promising model for other educational institutions to consider.

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Biography

MARK KINNEY
Mark Kinney became the Dean for Business and Technology at Bay College in July of 2012, but also served the college as the Executive Director of Institutional Research and Effectiveness in February 2009. Prior to that, Mark served as the Dean for Computer Information Systems and Technology at Baker College of Cadillac.

MARK HIGHUM
Mark Highum has served as a full-time faculty member at Bay College since 1996, with teaching positions in electronics, computer networking systems and security, and mechatronics and robotic systems. Prior to that, he served in the US Navy from 1977-1996 as an electronics technician in the nuclear power program.

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Aleksandr Sergeyev is an associate professor in the School of Technology at Michigan Tech University with areas of expertise that include electrical and computer engineering, physics, industrial robotics, automation, and adaptive optics. Sergeyev has industrial collaborations with GM, Ford, FANUC Robotics, BAE, Edmund Optics, Newport, and Texas Instruments.

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