# Professional Development Opportunity for Electrical Engineering Technology Educators in Robotics Automation

Aleksandr Sergeyev
EET, Michigan Tech
avsergue@mtu.edu

Nasser Alaraje
EET, Michigan Tech
alaraje@mtu.edu

## Abstract

Recently, educators have worked to improve STEM education at all levels, but challenges remain. Capitalizing on the appeal of robotics is one strategy proposed to increase STEM interest. The interdisciplinary nature of robots (which involve motors, sensors and programs) make robotics a useful STEM pedagogical tool. The real-world benefits of robotics, however, depend on workers with up-to-date knowledge and skills to maintain and use existing robots, enhancement of future robotics technologies and the education of users. With that, it is critical that education efforts respond to the demand for robotics specialists by offering courses and professional certification in robotics and automation. This NSF-sponsored project introduces a new approach for Industrial Robotics in Electrical Engineering Technology (EET) programs at Michigan Technological University and Bay De Noc Community College. The curriculum and software developed by this collaboration of two- and four-year institutions will match industry needs and provide a replicable model for programs around the US.

This paper describes an integral part of this project's dissemination effort - a 2-day faculty workshop aimed at providing an excellent professional opportunity for faculty members from other institutions who need to revamp their skills in robotics automation. The workshop will share combined knowledge gained through curriculum development with technical information from specific lab procedures. In addition, participants will learn how FANUC Robotics training can be integrated with practical curriculum planning and strategies for developing courses similar to those developed under this project.

## Project Background

Many existing jobs will be automated in the next 20 years and robotics will be a major driver in global job creation over the next five years. These trends are made clear in a study conducted by the market research firm, Metra Martech: "Positive Impact of Industrial Robots on Employment" [1]. Many repetitive, low-skilled jobs are being supplanted by technology. However, a number of studies have found that in the aggregate, the robotics industry is actually creating more jobs compared to the number of jobs lost to robots. For example, the International Federation of Robotics (IFR) estimates that robotics directly created 4 to 6 million jobs through 2011 worldwide, with the total rising to eight to 10 million if indirect jobs are counted. The IFR projects that 1.9 to 3.5 million jobs related to robotics will be created in the next eight years [2]. The rapid growth of robotics and automation (especially during the last few years) and its current positive impact and future projections for impact on the United States economy is very promising. Even by conservative estimates [1], the number of robots used in United States industry has almost doubled in recent years. In the manufacturing sector, the recent growth of installed robots was 41% in just three years! The number of robots per 10,000 workers employed in 2008 was 96. This number reached 135 in 2011. The United States automotive industry increasingly relying heavily on robotics is an example; China produces more cars than the U.S., but the number of robots used in vehicle manufacturing in China is estimated at 40,000, compared to 65,000 in the U.S. From 2014 to 2016, robot installations increased about 6% a year, resulting in an overall 3-year increase of 18% [1]. Likewise, industrial robot manufacturers are reporting 18-25% growth in orders and revenue year on year. While some jobs will be displaced due to the increased rollout of robots in the manufacturing sector, many will also be created as robot manufactures recruit to meet growing demand. Furthermore, jobs that were previously being sent offshore to low-wage economies are now being brought back to developed countries due to advances in robotics. For example, Apple now manufactures the Mac Pro in America and has spent approximately $10.5 billion in assembly robotics and machinery [3]. In March 2012, Amazon acquired Kiva Systems, a warehouse automation robotic system, and in 2013 deployed 1,382 Kiva robots in three Fulfillment Centers. This initiative did not reduce the number of employees at Amazon, but in fact it added 20,000 full-time employees to its U.S. fulfillment centers.

Such rapid growth of robotic automation in all sectors of industry will require an enormous number of technically sound specialists with skills in industrial robotics and automation to maintain and monitor existing robots, enhance the development of future robotic technologies and to educate future users on its implementation and application. It is critical, therefore, that educational institutions adequately respond to this high demand for robotics specialists by developing and offering appropriate courses geared towards professional certification in robotics and automation. In addition, certified robotic training centers (CRTC's) will be in high demand by industry representatives and displaced workers who need to retool their skills. This project will demonstrate and test an effective approach for teaching emerging topics of Industrial Robotics in Electrical Engineering Technology (EET) programs at both the university and community college levels. The curriculum and software developed in this initiative between a two-year and four-year institution will match current industry needs and will provide a replicable model for EET programs across the country. The project also addresses the need for CRTC's and provides curriculum and training opportunities for students from other institutions, industry representatives and displaced workers. Resources developed via this project will be disseminated through a variety of means, including workshops, conferences and publications.

**Educational Need**

Robotics is a great tool to help promote numerous STEM topics. Educators certainly have been making measurable progress toward improving STEM education from primary to tertiary levels, but continuing challenges remain. To help combat the current lack of student interest in STEM education, increased attention has been given to the appeal and attraction of robotics. The interdisciplinary nature of creating robots (involving motors, sensors, programming, etc.) makes it a useful pedagogical tool for many STEM areas. The novelty of robotics is instrumental in attracting and recruiting diverse STEM students. In the classroom, robotics can easily be used to introduce a variety of mandatory skills needed to pursue a variety of STEM career paths [15-17, 22, and 24]. More specifically, a robotics platform advances students' understanding of both scientific and mathematical principles [17, 18], develops and enhances problem-solving techniques [17, 18, 20-23], and promotes cooperative learning [17-19].

While robotics can be used as an interdisciplinary STEM learning tool, there is also a strong need for industrial certification programs in robotics automation. More and more robots are designed to perform tasks that people may not want to do, such as vacuuming, or are not able to do safely, such as dismantling bombs. Robots have changed the lives of Amyotrophic Lateral Sclerosis (ALS) patients by giving them the ability to speak after their vocal cords have failed, and have sparked our imagination in space exploration (not to mention our fascination with characters like R2D2). As many have put it, robots do our dirty, dangerous, and/or dull work. Millions of domestic/personal robots are already on the market worldwide, from lawn mowers to entertainment robots [25]. As a result, popular interest in robots has increased significantly [16-28]. Global competition, productivity demands, advances in technology, and affordability will force companies to increase the use of robots in the foreseeable future [39-41]. While the automotive industry was the first to use robotics, aerospace, machining, and medical industries now also rely on robotic automation [42, 43]. More than ever, trained and certified specialists are needed to maintain and monitor existing robots and to develop more advanced robotic technologies [39, 44-46].

As mentioned, robotics can be used as an interdisciplinary, project-based learning vehicle to teach STEM fundamentals [29-31]. Understanding the valuable role robotics education plays in helping students understand theoretical concepts through invention and creation, many universities include *components* of robotics research in curricular offerings [35]. It is widely recognized that robotics is a valuable learning tool that can enhance overall STEM comprehension and critical thinking [29, 36-38]. As a result of these benefits and industry needs, new programs in robotics automation and applied mobile robots are popping up in the U.S. and abroad. Industrial help from Microsoft, FANUC Robotics America Inc., and MobileRobots Inc., is essential to the growth of these programs. The objectives behind robotic programs are clear: 1) In the short term, robotics education fosters problem solving skills, communication skills, teamwork skills, independence, imagination and creativity [32-34]; and 2) in the long term, robotics education plays a key role in preparing a workforce to implement 21$^{st}$ century technologies. Currently, very few universities offer specific undergraduate robotics degrees. One of these, Worcester Polytechnic Institute (WPI), has offered a Bachelor of Science in Robotics Engineering since 2007 [50]. More so, universities have *graduate* degrees focused on robotics, including Carnegie Mellon University, MIT, UPENN, UCLA, WPI, and the South Dakota School of Mines and Technology (SDSMT). Michigan State University does have a well-established Robotics and Automation laboratory, but once again, it is utilized for graduate robotics courses and research. Likewise, very few universities across the U.S. offer certifications specifically in robotics automation. Lake Superior State University (LSSU) is another one of very few universities in Michigan that specializes in robotics automation; however, it does not have a program to certify industry representatives [47]. With few focused industrial robotics programs, undergraduate industrial robotics training often occurs in Electrical Engineering Technology (EET) programs, with the *focus* of the proposed program being EET.

Training in robotics automation is especially important to Michigan's economy. A major decline in automotive manufacturing jobs has left many areas in Michigan with high rates of unemployment. Baraga County, located 15 miles south of Michigan Tech, has one of the nation's highest rates of unemployment. Yet, Michigan has an unmet need for workers in robotics jobs [26, 48]. Filling these jobs, however, requires workers trained and certified in the following skill sets: designing, testing, maintaining and inspecting robotic components; troubleshooting robot malfunctions; using microcomputers, oscilloscopes, hydraulic test equipment, microprocessors, electronics and mechanics; and reading blueprints, electrical wiring diagrams and pneumatic/hydraulic diagrams. Driven by industry needs, the new curriculum designed in this project will be adapted to both two- and four-year programs. This project aims to address the current need in the U.S. workforce for properly prepared STEM professionals, train current industry representatives and displaced workers in robotics automation, educate K-12 teachers about current industrial robotics technologies and promote STEM fields among K-12 students.

## Project Core

Michigan Tech has built a very strong, multi-faceted curriculum in Robotics and Automation. Figure 1 depicts in-place and developing course work for two- and four-year institutions, high school teachers and students, industry representatives, and displaced workers.

The block at the upper-left corner of figure 1 shows two courses: 1) Existing Michigan Tech and Bay de Noc Community College Real-Time Robotics Systems course and its derivatives and 2) proposed new Robotics Vision course to be developed and implemented at both institutions. The block on the right side of figure 1 demonstrates training curriculum for students from other universities and community colleges, industry representatives and displaced workers.

The block at the bottom-left corner of figure 1 outlines a robotics curriculum model for K-12 teachers and hands-on training sessions for high school students conducted as part of this NSF sponsored project. The authors have provided a very detailed description [51-55] for all the curriculum models depicted in Figure 1 and therefore this information is omitted here. Though the project includes outreach to high schools, it is the authors' intention to focus this paper on the professional development opportunities in Robotics Automation developed as a part of this project for faculty members of two- and four-year institutions.

In addition to curriculum development, another important component of our work is a software created for this project called RobotRun. The program activity utilizes a 3D animated rendering of a robotic arm that is controlled via an intuitive programming language similar to software used to program real robotic arms. The programming language in our robotic arm simulator software provides all of the basic commands that exist in real-world robotics systems so that students can easily transfer the knowledge gained from the developed software to real-world robotic arms.

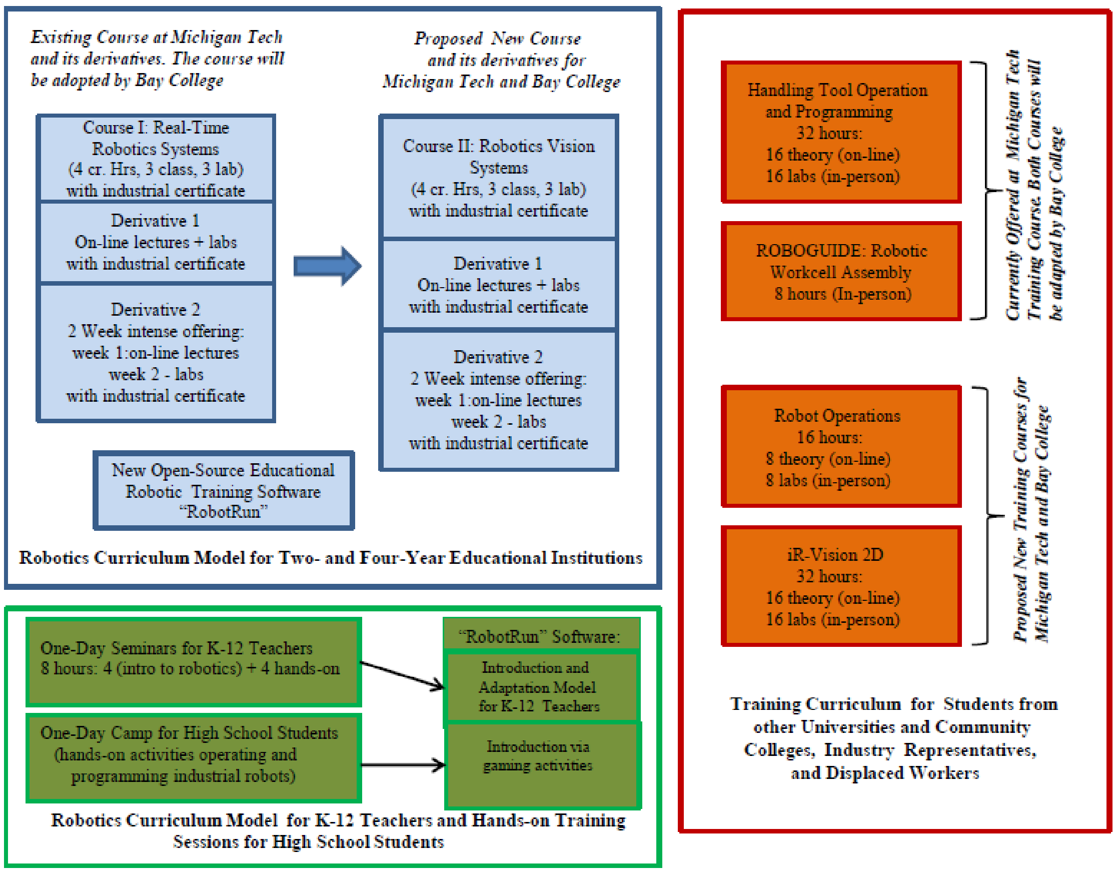


Figure 1: Proposed Robotics Automation Curriculum Development

The software allows the user to control where the end-effector should jog, at what speed and type of motion termination, how many times it should repeat the movement and other common robotics controls. Besides the option of jogging the robot and performing programming tasks, the software can be configured to present users with different scenarios that mimic real-world industrial scenarios such as pick and place, palletizing, welding, painting, etc. The program also allows users to load and save their programs so that they can turn them in to an instructor for grading. This new software provides all of the options necessary to teach required skills in robotics handling tool operation and programming. It is simple as well as intuitive, and omits the unnecessary features of expensive robotic simulation software packages designed for in-depth industrial simulations that are not typically used in educational settings.

An integral part of this project's dissemination effort are ***2-day workshops*** for up to 12 faculty participants. The project PI has developed and will lead the workshops over the course of three years in collaboration with faculty from Bay College. The workshops are being offered for faculty members from Michigan Tech's partner community colleges (Macomb Community College, College of Lake County, and Northcentral Technical College) that have already established articulation agreements with the EET program as well as interested EET faculty from other colleges and universities. The faculty workshops are scheduled to be conducted for three consecutive years at Michigan Tech and in Year 2 and 3 at Bay College. The main impetus behind the workshops is to share the combined knowledge gained through curriculum development efforts and the technical information derived from lab development experiences. In addition, participants will learn how FANUC Robotics training can be integrated through practical curriculum planning and strategies for developing courses similar to those developed under this project. These workshops are offered to faculty members of two- and four year institutions and are designed to increase practical experience in Industrial Robotics as well as renew the interest and empower those seeking to revamp existing courses or develop new courses in Industrial Robotics.

These 2-day, 16 contact hour workshops are designed to be an intense, immersive experience that provide a broad spectrum of activities to participants. The workshop starts by conducting a survey and pre-test. The survey, an anonymous questionnaire, is designed to collect the participant's feedback regarding attitudes towards different modes (in-person, online, or blended) of knowledge delivery. The purpose then of the pre-test is to assess participant's knowledge on the specific topics introduced during the workshop. During day one of the workshop, participants will be first familiarized with the structure of the curriculum developed at Michigan Tech and Bay de Noc. The theoretical topics covered during day one include: Concepts of robotic safety in an industrial environment, overview of the FANUC robots utilized in the development of the curriculum, robotic frames and how they impact a robot's motion, various robotic end-effectors commonly used in industry and effective programming of tool and user frames. In order to reinforce subject matter understanding, each theoretical topic covered during the workshop is followed by a hands-on activity. A total of three laboratory exercises are offered during the first day of the workshop.

Day 2 of the workshop starts by introducing the RobotRun educational robotic simulation software. A faculty member will demonstrate its' functionality, followed by participants being tasked to create several simulation projects. Theoretical topics covered during the second day of the workshop include: Concept or robot programming, data and position register instructions and how to use conditional and unconditional instructions to improve programming efficiency. Topics mentioned above are reinforced by three lab exercises. Day 2 of the workshop culminates with a survey, post-test and closing discussions during which time faculty members leading the workshop will provide recommendations on the possible implementation of this newly-developed robotics curriculum at other institutions.

A detailed agenda of the first faculty workshop to be conducted at Michigan Tech in Year 1 of the project is summarized below:

*Day 1:*

- Survey/Pre-Test
- Participants introduced to structure and details of the developed curriculum models for 2 and 4-year institutions (1 hr.)
- Topic 1: Industrial Environment Safety (30 min.)
- Topic 2: Overview of LR Mate Fanuc Robot (30 min.)
- Topic 3: Robotic Frames (1 hr.)
- Participants tour Robotic Automation Lab and learn more about both hardware and software necessary to establish a robotic automation lab at their respective institutions (1 hr.).
- Lab 1: Jogging in World and Joint Modes (1 hr.)
- Lunch Break 12:00 – 1:00
- Topic 4: End-of-Arm Tooling (1 hr.)
- Lab 2: Teaching Tool Frame (1 hr.)
- Lab 3: Teaching User Frame (1 hr.)

*Day 2:*

- Faculty participants familiarized with RobotRun educational training software. The faculty member leading the session will first demonstrate the functionality of the software, after which participants will be tasked to create several simulation projects (2 hrs.).
- Topic 5: Robot Programming (1 hr.)
- Lab 4: Basic Programming (1 hr.)
- Lunch Break 12-1
- Topic 6: Data and Position Register Instructions (1 hr.)
- Lab 5: Registers and Position Register Instructions (1 hr.)
- Topic 7: Conditional and Unconditional Branching Instructions (1 hr.)
- Lab 6: Conditional and Unconditional Instructions (1 hr.)
- Survey/Post-Test
- Discussions and Adjournment

The first workshop was advertised using engineering technology listserves and was filled within just fifteen minutes after posting the advertisement! An additional 45 faculties from institutions all over the United States are on a waiting list. This unquestionably indicates a high demand for robotic training, resulting from rapidly developing industrial automation (with robotics being in the top tier) across the entire industrial spectrum. It is the authors' goal to further increase awareness of robotic training available at Michigan Tech and Bay de Noc Community College via engineering technology listservs, conference proceedings and journal publications. This project's developed resources for faculty workshops and industry robotic training can be accessed here:
Faculty Workshop Resources (http://www.cs.mtu.edu/~kuhl/robotics/home.html );
Industry Robotic Training (http://www.mtu.edu/technology/robotics/ )

## Conclusion

There is significant demand from industry for well-prepared specialists capable of programming, maintaining and troubleshooting modern robots. As a result, the goal of this project was to develop a model curriculum and the associated tools that address current and future robotics industry expectations. In addition to enhancing STEM education at the college level, this collaborative project provides a template for how other institutions can bridge the gap between academia and industry, and academia and K-12. These bridges are critical for providing new resources to recruit and prepare a sustainable pipeline of graduates in robotics automation. Short-term outcomes include: Models for outreach that encourage early STEM interest, two certificates endorsed by industry and faculty development workshops to reach other universities and colleges.

Development of an advanced, industry-driven, hands-on educational curriculum in robotic automation will improve the quality of STEM education for EET students at two- and four-year institutions. The "RobotRun" software developed will be freely available for adaptation, which will allow robotics to be taught even when the purchase of industrial robots is not feasible. Faculty development includes extensive training and industrial certification in robotics and automation. Collaboration and dissemination will align Michigan Tech robotic automation education with industry needs. As a result of the project, engineering technologists will enter the workforce prepared to adapt to the complex and changing demands of tomorrow's high-tech automated workplace.

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## Biographies

**ALEKSANDR SERGEYEV** is Associate Professor in the Electrical Engineering Technology program at Michigan Tech. He is a FANUC certified instructor in Robotics and oversees all activities of the FANUC authorized certified training center at Michigan Tech. He has developed and taught courses in the areas of Robotics and Automation, Power, Electrical Machinery, Programmable Logical Controllers, Digital Signal Processing, and Optics. He has a strong record publishing in prestigious journals and conference proceedings such as Measurements Science and Technology, Adaptive Optics, Sensors and Materials, The Technology Interface International Journal, ASEE, IEEE, and SPIE. Additionally, Dr. Sergeyev is a Co-PI on several NSF and DOL awards, and a PI on multiple significant industry awards. Dr. Sergeyev may be reached at avsergue@mtu.edu

**NASSER ALARAJE** is Associate Professor and Program Chair of Electrical Engineering Technology at Michigan Tech. In 2009, Alaraje was awarded the Golden Jubilee by the College of Engineering at Assiut University, in Egypt. He has served as an ABET/IEEE-TAC evaluator for electrical engineering technology and computer engineering technology programs. Dr. Alaraje is a 2013-14 Fulbright scholarship recipient at Qatar University, where he taught courses on Embedded Systems. Additionally, he is the recipient of an NSF award for a digital logic design curriculum revision in collaboration with College of Lake County in Illinois, and an NSF award in collaboration with University of New Mexico, Drake State Technical College and Chandler-Gilbert Community College, focused on expanding outreach to increase awareness of precollege students about career opportunities in electronics technologies. Dr. Alaraje may be reached at alaraje@mtu.edu