Development of a Smart Manufacturing Technology Earn and Learn Program at a Rural Community College

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Abstract: Manufacturing continues to be a vital component of the Ohio economy. Ohio's manufacturing sector employs over 600,000 skilled individuals, the third-largest manufacturing workforce in the U.S. [1]. With additional manufacturing industries moving into Ohio, including Intel and its supply chain partners, there is a growing need for industry-ready, skilled engineering technicians. In addition, with the increasing use of automated systems and network connectivity of these systems in manufacturing operations, technicians need to be equipped with skills in the area of smart manufacturing. This article details the development of a Smart Manufacturing Technology (SMT) associate's degree that is modeled as an earn-and-learn program. The program is equipped with various experiential learning opportunities, and additional industry-recognized certifications are embedded within specific courses. Summer camps were designed and delivered to expose middle and high school students to smart manufacturing and to build a pipeline of students into this program. A professional development summit was delivered each year of the grant. The purpose of the summit was to increase high school instructors' awareness of smart manufacturing so that they can better advise students about this in-demand field and teach courses in the SMT pathway.

Keywords: work-based learning, smart manufacturing, Industry 4.0, industry certification, earn and learn

Introduction

The manufacturing industry continues to grow and requires a workforce of skilled technicians to ensure operations run smoothly and effectively troubleshoot problems so that downtimes are minimized. According to Deloitte and the Manufacturing Institute, estimates indicate that the skills gap may leave 2.4 million positions unfilled between 2018 and 2028 [2]. The skills gap analysis suggests that the top three causes of skills shortage are shifting skill sets due to increased automation, negative perceptions about manufacturing careers, and baby boomer retirements [2].

The National Association of Manufacturers report shows that Ohio manufacturers account for 16.12% of the total output in the state, employ 12.74% of the workforce, and the total output from manufacturing

was $112 billion in 2019 [3]. The 2020-21 Ohio Manufacturing Counts report from The Ohio Manufacturers' Association (OMA) shows that "Ohio has ranked second nationally in the total number of new site selections in the past eight years" [4]. The report also shows that locally, in Marion County, Ohio, manufacturing accounts for 19.8% of total county employment [4].

As a result of the pandemic, significant supply chain disruptions have also adversely affected the U.S. manufacturing industry. The pandemic has also confirmed the need for manufacturers to be able to source key devices and components locally to avoid delays in their internal operations. This includes semiconductor chips for use in a variety of engineering components and applications. In September 2022, Intel began constructing two new leading-edge microchip manufacturing facilities in Licking County, Ohio. Licking County is 47 miles from Marion Technical College (MTC), which is located in Marion County. Intel will hire 3,000 individuals in the next three years in semiconductor manufacturing, and they have stated that two-thirds (~2,000) of their employees will be associate degree-prepared engineering technicians. As the U.S. manufacturing industry positions itself to be more self or "locally" reliant and remain competitive in the global market, an adequate, skilled, technical workforce is needed to fill key advanced manufacturing roles, including those related to smart manufacturing or Industry 4.0.

According to the National Institute of Standards and Technology (NIST), the term smart manufacturing describes "fully integrated, collaborative manufacturing systems that respond in real time to meet changing demands and conditions in the factory, in the supply network, and in customer needs" [5]. Smart manufacturing is the application of smart technology such as sensors, controllers, and data storage in the manufacturing industry, as well as the integration and connectivity of these devices throughout operations. This allow for the maximization of plant efficiency and accuracy using real-time data. At the same time, the movement of the manufacturing industry toward the smart manufacturing approach requires a skilled workforce in the maintenance and troubleshooting of these systems.

In order to ensure graduating engineering technicians are prepared to successfully transition into industries implementing smart manufacturing, engineering technology programs integrating work-based learning are highly desirable. Work-based learning, also referred to as experiential learning or on-the-job training, is spread throughout an engineering technology students' academic program, allowing them to practice the knowledge and skills learned in the classroom. It also allows employers to directly impact developing their future workforce.

The Ohio Department of Education defines the following as the guiding principles behind work-based learning [6]:

- Work-based learning experiences must occur at a work site.
- Work-based learning experiences must be co-supervised by an instructor or other educational representative and an employer or business mentor.
- A learning agreement built on professional, academic, and technical competencies aligned to the student's program of study, student success, or graduation plans must be in place.

In 2013, Honda North America's shortage of technically skilled workers, specifically in electro-mechanical support, proved challenging [7]. A partnership between Columbus State Community College (CSCC) and Honda North America resulted in the development of the Modern Manufacturing Work Study (MMWS) program in 2013 [7]. CSCC's earn-and-learn model approach embeds students within a company for up to 18 months. During this time, the student engages in paid work/on-the-job training part-time three days per week while attending classes full-time two days per week [7]. Refer to Figure 1 for the MMWS framework.

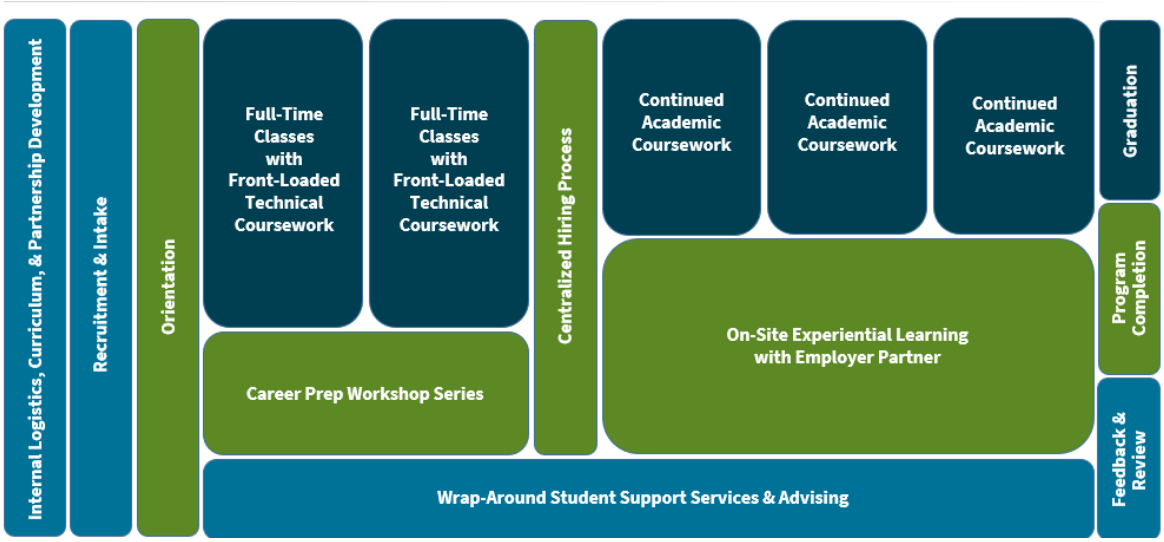

Fig. 1. Framework for Columbus State Community College's Modern Manufacturing Work Study Program [7]

Similarly, in 2015, Lorain County Community College (LCCC) partnered with Team NEO, a regional economic development entity, to assemble employers to partner on developing an earn-and-learn program [7]. The earn-and-learn programs described are embedded within existing engineering technology programs at the College (such as electro-mechanical engineering technology, automation engineering technology, etc.). They are not necessarily embedded within a fully integrated smart manufacturing program combining key aspects of automation (process control, robotics, etc.) and information technology (sensor and controller connectivity, manufacturing networking and cybersecurity, etc.).

This work will outline the development of a Smart Manufacturing Technology Associate of Applied Science degree at MTC. This program is modeled as a paid earn-and-learn program, embedded with experiential learning opportunities, a career readiness course, and industry-recognized credentials. MTC incorporated the year-long work placement model, similar to the colleges mentioned above, to provide students with longer on-the-job training, which could allow them to experience multiple departments within a given company. It would also better prepare students to transition to a full-time technician or maintenance position with the same company or another, with less training to be provided by the employer. Similar to CSCC's MMWS program, progressing students through MTC's earn-and-learn program will also involve more frequent check-ins with the student's supervisor/mentor. This is to ensure that the student is performing/progressing well and to gain feedback on skills the student may be lacking, which can be used to update the current curriculum. Other key program features, including the curriculum, training for instructors to provide industry certifications, smart manufacturing-related professional development events for high school instructors, and wraparound services to prepare students for the work placement, will be discussed along with recommendations. Currently, the work placement is not for credit. Events organized and carried out to recruit middle and high school students into this new program will also be addressed in addition to the external evaluation of the efficacy of this initiative.

Methods

The Smart Manufacturing Technology earn and learn program is the first of its type at MTC. The other Associate of Applied Science or Associate of Technical Studies programs offered in the Engineering Technologies Department at the College (Electrical Engineering Technology, Electrical Engineering

Technology – Alternative Energy Option, and Robotics and Automation Engineering Technology) require students to complete a 150-hour industry co-op in their final term of the program. As per the Ohio Department of Higher Education (ODHE), these programs are required to include 30-35 semester credit hours of technical courses and 30 semester credit hours of non-technical courses, including a minimum of 15 semester credit hours of general education courses and the remaining semester credit hours made up of applied general education courses.

The development of the SMT earn and learn program was one of the outcomes of a three-year National Science Foundation (NSF) Advanced Technological Education (ATE) grant awarded to MTC in 2020. The grant title is "Bridging the Skills Gap in Smart Manufacturing through a New Technician Education Program," the award number is 2000177. The program was developed to build a pipeline of students with both technical and on-the-job training to fill existing and upcoming engineering technician and maintenance roles with local manufacturers. More specifically, students completing this program will be well suited to work in such areas as controls, robotics (integration, operation, and troubleshooting), and manufacturing cybersecurity. The program is structured so that students complete technical courses in the first two semesters and general education courses in the third semester of the program. In their fourth and fifth semesters, students complete the remaining technical courses two days per week and complete paid on-the-job training at a manufacturing facility the other three days of the week. Table 1 below shows the term-by-term curriculum for the SMT earn and learn program.

Table 1. MTC Smart Manufacturing Technology Curriculum

Course code	Course title	Credits
FIRST SEMESTER (FALL)		
GET1000	Introduction to Engineering	2
EET1000	Introduction to Electricity	2
EET2010	Introduction to Programmable Controllers	2
TMT1110	Applied Technical Math	3
CIT1100	Introduction to Programming Concepts w/Python	3
OIS1240	Computer Applications	3
FYE1000	Academic and Career Success	1
SECOND SEMESTER (SPRING)		
EET2510	Automated Process Control	3
EET1500	Circuit Analysis I	3
SMT1200	Instrumentation and Control	2
EET2060	Advanced Programmable Controllers	3
ENG1000	English Composition	3

MET1500	Mechanical Drives	3
THIRD SEMESTER (SUMMER)		
COM1400	Oral Communication	3
SOC2020	Ethnic and Cultural Diversity	3
EXP2800	Career Readiness	1
SOC1200	Sociology	3
or		
PSY1100	Introduction to Psychology	3
FOURTH SEMESTER (FALL)		
EET1550	Circuit Analysis II	3
SMT1100	Cybersecurity and Networking in Manufacturing	3
EET1301	Robot Handling Tool Operations and Programming	2
MTH1245	College Algebra	3
FIFTH SEMESTER (SPRING)		
PHY1110	Applied Physics	4
GET2300	Engineering Statistics	2
SMT2000	iRVision Operation and Programming – 2D	2
TEC0000	Technical Elective	3

Three new courses were developed for the SMT curriculum, given in Table 1. The other courses were taken from existing Engineering Technology programs at the College. The new courses include SMT1100 (Cybersecurity and Networking in Manufacturing), SMT1200 (Instrumentation and Control), and SMT2000 (iRVision Operation and Programming – 2D). These courses were developed in consultation with MTC's Engineering Advisory Committee, which indicated the current and future need for technicians with experience installing and troubleshooting instruments and devices. They also expressed the need for technicians to have a working knowledge of programmable logic controllers and robotic vision, both in terms of the hardware and basic troubleshooting. Local employers have indicated the advantages of training/upskilling existing employees, as opposed to subcontracting work externally, in order to keep delays and costs to a minimum—creation of the new courses involved the development of lecture material, assessments, and lab activities. Process control equipment to support the SMT1200 course was purchased with NSF grant funding. This equipment is used to control the fluid in a tank to a

specified level, as is typical in a manufacturing or food production facility. The SMT1200 course allows students to install, operate, and troubleshoot sensors (flow, pressure, temperature, etc.), understand how these sensors serve as inputs to a controller, and see how these devices are network-connected for predictive and/or preventative maintenance purposes.

In the third semester of the program, students take a Career Readiness course (EXP 2800) to prepare for work placement in the fourth and fifth semesters. This course aims to help students transition from the classroom to the world of work. Each student will conduct a job search, practice interview techniques, improve upon personal and professional communication skills, and develop a functional resume. In the third semester, students will also work with the Career Services Department at the College to secure a work placement and to complete all of the required documentation (employer and College) related to the work placement. For example, before the student begins the work placement, an employer agreement form is completed in consultation with the placement employer/supervisor. The form requires that the student and the supervisor outline a learning plan (i.e., activities that the student will be involved in during the course of the placement or an on-the-job training checklist) as well as any training required as part of the students' onboarding with the corresponding completion dates. In addition, there is an area on the form for a member of the Career Services team to document student performance and progress at equal intervals based on feedback from the employer and the student (verbal, written, etc.). At the end of the placement, the student will complete a presentation, guided by a formal rubric, summarizing their on-the-job training. After the yearlong work placement, the student and the employer will also complete a written evaluation.

It is expected that the student will be engaged in duties during the work placement that apply or build on the skills gained in the first year of technical coursework. For example, if the student is employed in a robotics capacity, key skills that they will apply from robotics courses taken in the program may include:

- Jogging the robot to a target position and recording a position value (position register) using the teach pendant
- Opening an existing production program and modifying a position value (position register)
- Creating a basic robotic program as well as testing and running the program. This may also involve adjusting speed, force, and to run in step, cycle, and continuous modes.
- Setting up collision avoidance and detection
- Backing up and restoring program files, system parameters, and control software images

The Smart Manufacturing Technology earn and learn program also has shorter-term experiential learning opportunities embedded in the curriculum before the yearlong work placement. For example, in the GET1000 (Introduction to Engineering) course in the program's first term, each student is required to complete a four-hour industry job shadow. With support from the College's Career Services Department, students select a company to complete their job shadow experience. Typically, the students will shadow an operations, maintenance, production, or quality technician to gain insight into their role, daily activities, and involvement with other areas of the company. The students are also required to complete a short personal reflection at the conclusion of the job shadow.

The program is also set up so that students have the opportunity to obtain three additional industry-recognized certifications in addition to the associate's degree. Table 2 lists the three industry-recognized certifications and the requirements for obtaining the certifications.

Table 2. Additional industry-recognized certifications embedded in the SMT program

Course	Industry certification	Requirements to obtain certification
GET1000 (Introduction to Engineering)	OSHA-10	Complete 10-hour online module
EET1301(Robot Handling Tool Operations and Programming)	FANUC Handling Tool Operations and Programming	Complete course
SMT2000 (iRVision Operation and Programming – 2D)	FANUC iRVision Operation and Programming – 2D	Complete course

In order to be able to grant students the FANUC certification, the faculty member must achieve a "Train-the-Trainer" status. The first step towards the faculty member obtaining this designation includes completing training on the software and equipment provided by the manufacturer (FANUC). The second step entails the faculty member submitting a teaching video (to FANUC) covering at least one topic related to the operation of the equipment covered in the certification. This video would need approval from FANUC.

As part of the NSF ATE grant, funding was also provided to organize and deliver outreach events to expose middle and high school students to smart manufacturing and to build a pipeline of students into the new SMT program. A four-day SMT summer camp was delivered each year of the grant (2021-2023) during the summer. The camp was open to participants ages 12-18 years and was free of charge. Due to the high interest in the camp, a morning session and an afternoon session were made available. The maximum number of students per session was set at 12. The first two days of the camp had an information technology (IT) focus where students learned about using sensors, programming using a Raspberry Pi, and the hardware and software aspects of controlling a drone. Raspberry Pi Sense HAT units and CoDrone Pros were purchased, using grant funds, for camp participants to work together in teams of two. The third day of the camp focused on advanced manufacturing and industrial robotics. The participants learned about the operation and programming of industry-scale robots (FANUC and Yaskawa) and troubleshooting a mini factory line equipped with sensors, relays, and controllers. The participants spent time in the College's Esports Arena on the fourth and final day, participating in gaming activities. T-shirts, water bottles, and drawstring bags with the College's SMT logo were purchased with grant funds and given out to participants at the conclusion of the camp.

A participant survey, designed by the program evaluator on the project team (Ms. Blake Urbach, Principal Consultant of Preferred Program Evaluations), was administered to gain feedback on the effectiveness of the 2022 camp in engaging participants and increasing their understanding of and interest in smart manufacturing. On the last day of the camp, the online survey was administered to the participants, the results were compiled, and the program evaluator provided a dashboard summary. Twenty participants completed the electronic survey. All of the respondents identified as male. Seventy percent of respondents were middle school students (grades 6-8), and the other 30% were high school students (grades 9-12). Overall, the participants were satisfied with the camp activities and their interactions with the instructors, student volunteers, and peers. Eighty-five percent of participants agreed that the camp strengthened their interest in continuing to study smart manufacturing, and nearly all of the respondents would recommend this camp to their contemporaries. Figure 2 below provides a few sample questions from the survey. Participants were asked to rate their experience at the summer camp using a Likert scale of "strongly disagree" to "strongly agree," which has been consolidated in this table.

	Criteria	Agree (%)	Disagree (%)
Strengths	Camp activities offered plenty of time for hands-on engagement	95	5
	More knowledgeable about robotics and control prior to participating	85	15
	Strengthened my interest in studying smart manufacturing technology	85	15
Weaknesses	The length of this camp was the right amount of time to complete the activities	65	35

Fig. 2. 2022 SMT Summer Camp Participant Survey results

A professional development summit intended to increase local high school instructors' awareness and competencies related to smart manufacturing was delivered in the summers of 2021-2023. These events were organized to be a combination of two to three of the following: industry keynote speakers, a presentation covering progress on SMT grant-related activities, an SMT student panel, and breakout sessions providing participants with demos and hands-on activities using the industry scale equipment supporting the SMT curriculum. The summit also allowed participants to network with one another, the Engineering and IT faculty, and the grant project team members. As with the summer camp, the program evaluator designed a comprehensive participant survey. The purpose of the survey was twofold. The first was to provide an understanding of how to best serve high school instructors, particularly those teaching in the career technical education (CTE) area, with professional development engagements in the discipline. The second was to encourage introducing smart manufacturing concepts into existing courses taught by high school instructors and to gage their interest in delivering (at the high school) college credit plus (CCP) or articulated courses which feed into the SMT pathway.

Results and Discussion

Currently, ten students (as of Fall 2023) have declared this program as their primary major or as one of their majors if they complete multiple majors. When asked if the earn-and-learn component influenced their decision to enroll in this degree program, one student shared, "The fact that I'm already employed makes the earn-and-learn degree more feasible." Another added, "Earn-and-learn works well with my work schedule, plus I can beef up my resume." The students shared that the technical skills they gained and/or improved due to completing SMT courses included troubleshooting, mechanical skills, writing

instructions for machines, and programming a logic controller. Reported gains and improvement in soft skills included problem-solving, critical thinking, and communication.

In consultation with employer partners, internal college departments (Career Services, Academic Advising, etc.), and utilizing feedback from stakeholder interviews carried out by the program evaluator, the project team will continue to look at ways to improve the earn and learn program. The project team has already identified one area where an improvement would need to be made. For example, currently, there are no credit hours associated with the two-semester work placement. Theoretically, students could complete the degree without completing the work placement, although this is a requirement of the degree and relayed to the student in initial advising meetings. One option would be to replace the three-credit hour Technical Elective course (TEC0000) with two work placement courses (i.e., Earn and Learn 1 and Earn and Learn 2). Earn and Learn 1 (one credit hour) would be taken in the fourth semester, and Earn and Learn 2 (two credit hours) would be taken in the fifth semester. Each credit hour equates to 150 hours of on-the-job training, so students must complete a minimum of 450 hours of paid work to get credit for the two courses.

The sustainability of the SMT earn and learn program and a plan for continuing to deliver yearly outreach events such as the SMT summer camp are under discussion. Since the camp is open to students at the middle school level, the intent is that these students will continue to attend the camp each year until they matriculate to MTC into the SMT (or other engineering technology) program. Discussions on whether to hold separate camps for middle and high school students are also underway. Incorporating an additional question at the end of the camp survey to gauge high school students' interest in enrolling in the Smart Manufacturing program directly after graduation would also be helpful. This would allow Advisors, Admissions, and the Engineering team to perform further outreach and stay connected to these students. Supplies for activities to engage these students each year, without repetition or duplication of activities, will be an important point to consider. As a start, grant funds have been used to purchase various kits and outreach material/giveaways for future camps and to engage students at various skill levels.

Conclusion

With the increased need for engineering technicians to fill Industry 4.0 roles, engineering technology programs with embedded work-based learning opportunities will ensure graduates are work-ready. The Smart Manufacturing Technology earn and learn program, outlined here, incorporates two terms of on-the-job training, ample hands-on labs centered around automation systems, and the opportunity to obtain additional industry-recognized certifications. Summer camps are being delivered to expose local middle and high school students to the IT and engineering aspects of smart manufacturing and to build a pipeline of students into the new program. Further data (both qualitative and quantitative) will need to be collected to assess student performance at work placement sites as well as overall employer satisfaction. It is expected that this program can be replicated at other community colleges looking to prepare technicians for Industry 4.0 roles.

Acknowledgements. This work was supported by the National Science Foundation (NSF) under award 2000177.

Disclosures. The authors declare no conflicts of interest.

References

[1] JobsOhio, "Advanced Manufacturing," https://www.jobsohio.com/industries/advanced-manufacturing/.

[2] Craig Giffi et al., “2018 Deloitte and The Manufacturing Institute Skills Gap and Future of Work Study,” https://www2.deloitte.com/content/dam/insights/us/articles/4736_2018-Deloitte-skills-gap-FoW-manufacturing/DI_2018-Deloitte-MFI-skills-gap-FoW-study.pdf.
[3] National Association of Manufacturers, “2021 Ohio Manufacturing Facts,” https://www.nam.org/state-manufacturing-data/2021-ohio-manufacturing-facts.
[4] The Ohio Manufacturers’ Association, “2020-21 Ohio Manufacturing Counts,” https://www.ohiomfg.com/wp-content/uploads/OMA_ManufacturingCounts2020.pdf.
[5] National Institute of Standards and Technology (NIST), “Product Definitions for Smart Manufacturing,” https://www.nist.gov/programs-projects/product-definitions-smart-manufacturing.
[6] Ohio Department of Education, "Ohio Guide to Work-Based Learning,” https://education.ohio.gov/getattachment/Topics/Career-Tech/Work-Based-Learning/Work-Based-Learning-for-Businesses-and-Communities/Employer-Guide-to-Work-Based-Learning.pdf.aspx?lang=en-US.
[7] Columbus State Community College and Loraine County Community College, “Advanced Manufacturing: A Look at Two of Ohio’s Most Innovative Earn-and-Learn Models Replication Guide 2020,” https://ohiotechnet.org/wp-content/uploads/2020/07/EARN_Project_Replication_Guide.pdf.