DESIGN AND IMPLEMENTATION OF AN INDUSTRY 4.0 MICRO-CREDENTIAL PROGRAM

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Abstract – *Traditional post-secondary education models are designed for students looking to enter the skilled labour market rather than up-skilling or re-skilling the existing labour market. Micro-credentials, which are short-duration courses available outside of credited degree programs, are a promising mechanism for post-secondary institutions to engage in these continuing education opportunities. In this paper, we present a micro-credential program that is complementary to the existing engineering degree program while also relevant and accessible to industry. The program contributes to a larger micro-credential movement within the province of British Columbia and provides a model for other institutions looking to enter and collaborate within the micro-credential ecosystem.*

Keywords: Micro-credentials, Industry 4.0, non-credit credentials, competency-based assessment.

1. INTRODUCTION

Micro-credentials are short duration, competency-based, stand-alone courses that have been gaining interest among post-secondary institutions, industry, and the government [4]. The British Columbia (BC) Ministry of Advanced Education and Skills Training (MAEST) has identified micro-credentials as part of a solution to meet the needs of a rapidly evolving economy and increasing labour shortages. In an effort to formalize the design and delivery of micro-credentials the BC MAEST has published a set of guiding principles to formalize the development of micro-credential programs to meet the needs of industry, governments, and institutions [3]. Namely, micro-credentials should be (i) accessible to a broad range of learners, (ii) governed by a process to ensure quality, (iii) relevant to industry, government, and institutional priorities, (iv) developed in coordination with other post-secondary institutions, (v) developed and improved in consultation with industry, (vi) clear and transparent regarding the competencies attained. From an institutional perspective, micro-credentials are effective in attracting learners into traditional degree programs, providing continued professional development, and can provide an additional revenue stream.

In this paper, we present the design and implementation of an Industry 4.0 micro-credential program. Industry 4.0 is a term that emerged around 2015 to describe the ongoing trend towards highly connected and smart automation in the manufacturing sector [9]. Many see Industry 4.0 as a fourth industrial revolution (hence the nomenclature) causing an economic disruption economy comparable to the invention of the steam engine in the late 1700s, the assembly line in the early 1900s, and robotics/automation in the late 2000s. Equipping the workforce and students with Industry 4.0 competences is essential for the Canadian manufacturing sector to remain globally competitive.

Although the definition of Industry 4.0 remains a point of discussion, there is a general consensus that factories adopting Industry 4.0 standards have the following capabilities [5]:

- Interconnectivity – machines, devices, and people exchange data with each other.
- Information transparency – operational and business information is available to decision makers.
- Artificial intelligence – technology has the ability to make decisions or assist people in making decisions.
- Decentralized decisions – machines operate autonomously and in collaboration.

The focus of the micro-credential that is presented in this paper is on Industry 4.0 standard automation technology [6], specifically Programmable Logic Controllers (PLCs).

Selected methodology – The proposed micro-credential program was designed in partnership with the University of British Columbia, Okanagan campus (UBCO), the National Coalition of Certification Centers (NC3), and Festo Didactic. In this context, UBCO is an NC3 qualified certification center and delivers the micro-credential. The qualification of a certification center follows a quality control process enforced by NC3. NC3 certifications are created in partnership with industry leaders such as Festo Didactic, the education and training division of globally recognized industrial automation company Festo [2]. This industry engagement ensures that the competencies gained by learners are relevant to the needs of industry. The micro-credential program is designed for both learners looking to up-skill or re-skill as well as students in engineering degree

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programs [8]. Upon successful completion of the micro-credential, learners receive a UBCO Letter of Proficiency, a digital badge, and an NC3/Festo certificate.

Significance of the results – The proposed micro-credential program serves as a model for other institutions to create similar programs. In particular, this micro-credential was designed to align directly with the guiding principles outlined by the BC MAEST and therefore it is a step towards establishing a high impact multi-institutional micro-credential ecosystem. Future work will focus on (i) contributing to a micro-credential registry to promote transferability and reduce duplication between institutions, (ii) expanding into other industries, (iii) developing micro-credentials for secondary students to generate interest in STEM topics, and (iv) developing learning management systems (LMSs) to better support micro-credential programs [7].

Organization – The NC3 certification model will be discussed in the next section followed by a description of the Industry 4.0 micro-credential program in Section 3. The paper concludes with some results and discussions in Section 4 and conclusions and future work in Section 5.

2. NC3 CERTIFICATION MODEL

The National Coalition of Certification Centers (NC3) is a 501c3 not-for-profit corporation based in the United States whose mission is to help develop a skilled workforce to meet the needs of industry [1]. Its approach is to facilitate industry-recognized certifications by establishing and supporting industry-educational partnerships. The core services offered by NC3 include curriculum development, train-the-trainer events, testing, and program and site assessments. NC3 is funded through industry contributions and post-secondary institution memberships, thus reducing the financial barrier for students to earn certifications. There is no fee for students to write NC3 certification exams.

2.1. Industry partnerships

At the core of the NC3 model are industry partnerships. As of the time of writing, NC3 is partnered with sixteen companies who are global leaders within their domain of expertise. Together, NC3 and the industry partners create flexible and stackable certifications to provide students with relevant technical skills in sectors such as transportation, construction, energy, manufacturing, welding, aviation, health & safety, STEM, horticulture, and digital literacy. To earn a certificate, students must demonstrate competency in both the theoretical and hands-on application of the skills taught; the relevant industry partner provides the hardware platform used for the hands-on training of students.

Relevant to this paper is the NC3-Festo partnership and the manufacturing certification program. Festo is a German-based industrial automation company that produces pneumatic and electrical devices used for factory control and automation. The didactic side of the company provides solutions for technical education. Festo learning systems are designed with industrial-grade equipment and software that students are likely to encounter in the manufacturing sector. In particular, Festo Didactic offers a line of Industry 4.0 training solutions that form the backbone of the manufacturing certification program illustrated in Fig. 1.

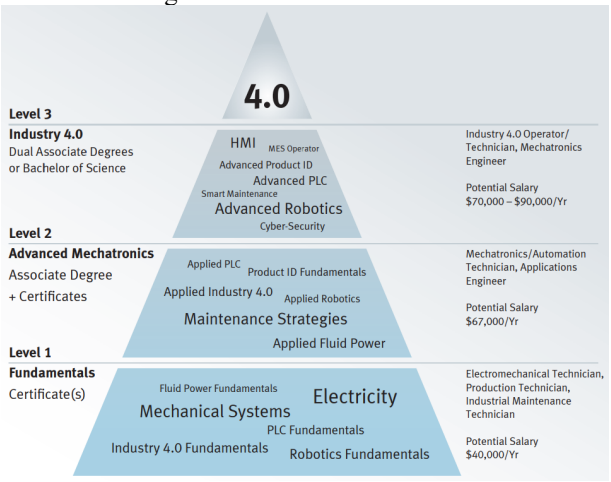


Fig. 1. NC3/Festo Industry 4.0 certification program presented to highlight the horizontal (across topic areas) and vertical (relative to level of expertise) stackability of certificates.

2.2. Educational institution partnerships

In the NC3 model, educational institutions and their faculty become qualified to offer certifications. Institutions can engage at three levels: entry ("Certification Center"), strategic start ("NC3Start School"), and premier ("Leadership School"). At all three levels, institutions have access to instructor training through train-the-trainer events, access to discounted equipment through NC3 industry partners, and use of the NC3 learning management system (LMS). The NC3 LMS hosts curriculum material and manuals, a testing platform for students to demonstrate their theoretical competence, issues digital certificates to students upon completion of a credential, and records data (e.g. type and number of certificates issued, student performance, etc.). At the premier level of engagement, institutions can become qualified to offer any NC3 certificate through any industry partner, participate in vision and benchmarking, and participate in exclusive events and activities hosted by NC3.

The process for an institution to become an NC3 Certification Center starts with a faculty member/instructor attending a train-the-trainer event. Faculty can become qualified to issue certificates in a number of topic areas at train-the-trainer events, which are hosted regularly throughout the year in various locations across the United States. At a train-the-trainer event, instructors are trained

by master instructors on the certificate topics and how to best deliver the content to students. Train-the-trainer events ensure that all instructors are delivering certificates at the same level of qualification. Instructors must pass the theory portion of the course with a grade of 80% to become qualified. The institution must also purchase and install the proper equipment, which is supplied by the industry partner, needed to deliver the certificate. Once the institution has the equipment and a trained instructor the NC3 LMS is opened up to begin delivering the certificate to students.

Fig. 2. Sample NC3/Festo certification. The back (bottom image) of the certificate lists the certification competencies demonstrated by the learner.

2.3. Learner experience

The path towards earning an NC3 certificate begins with a potential learner choosing a certification center, in this case UBCO. The price, if there is one, of the micro-credential is set by the certification center and not NC3; writing an NC3 exam is free for learners. Learners must participate in the theory (lecture) component of the micro-credential and complete the hands-on activities in the NC3 lab manual before the instructor provides learners with access to the NC3 exam on their LMS. Learners have three attempts at the exam to earn a grade of 70%. If they are successful, a digital certificate is issued to the learner (see Fig. 2).

3. INDUSTRY 4.0 MICRO-CREDENTIAL PROGRAM AT UBC

3.1. Academic context

The Manufacturing Engineering program at the University of British Columbia was established in 2018, with its first cohort of students graduating in the spring of 2022. The program was started in coordination at both the Vancouver and Okanagan (UBCO) campuses and the program received accreditation from the Canadian Engineering Accreditation Board (CEAB), also in the spring of 2022. The program at UBCO focuses on three areas of manufacturing: engineering management, manufacturing science/processes, and production system technology. Of relevance to this paper, production system technology courses such as Industrial Automation, Engineering Measurements and Instrumentation, Factory Planning, and Digital Enterprise are designed to provide graduates with the technical skills to succeed in the Industry 4.0 era.

A substantial capital investment was made by the university in 2019 to outfit the manufacturing labs with state-of-the-art equipment. A major consideration when purchasing equipment was the ability to offer certifications to students within the program and also support the development of career and technical education (CTE) programs. Because of the strong alignment of the expertise of the faculty in the Manufacturing program and NC3/Festo certification program, a number of learning systems from Festo Didactic were purchased, including:

- Modular Production Systems (MPS) – lab scale conveyor systems with a variety of industrial application modules (pick-and-place, sorting, dispensing, etc.) controlled by industrial PLCs.
- MPS 403 – a complete Industry 4.0 conveyor system equipped with smart sensors, RFID tracking, machine vision, and a manufacturing execution system (MES). See Fig. 3.
- Industrial Robot Assembly Station – a FANUC LR Mate 200iD robot mounted on a Festo assembly station.
- Cyber-physical Laboratory – a complete Industry 4.0 factory simulating the assembly of a cell phone equipped with smart sensors, RFID tracking, and a manufacturing execution system.
- Industrial Sensor and Smart Sensor Trainers – trainer boards that allow characterization and testing of common industrial sensors and IO-Link communication.

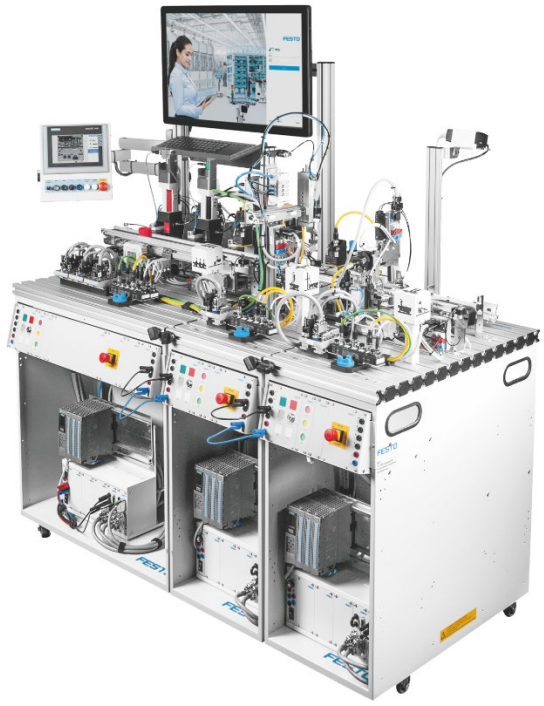


Fig. 3. A Festo Didactic Modular Production System 403 used to train students in a number of Industry 4.0 technologies.

With this equipment, UBCO became a qualified NC3 certification center with the ability to offer the following NC3/Festo level 1 (Fundamentals) certificates:

- Fundamentals of Industry 4.0,
- Fundamentals of Robotics,
- Fundamentals of Sensor Technology,
- Fundamentals of PLCs (Siemens),

and the flowing level 2 (Advanced Mechatronics) certificates:

- Applied Industry 4.0,
- Applied Product ID Fundamentals,
- Applied Robotics,
- Applied Principles of Smart Sensors,
- Applied PLC Technology II (Siemens).

Level 3 (Industry 4.0) certification is currently underdevelopment in partnership with NC3/Festo. When it is deployed UBCO will be qualified to offer all Level 3 certificates with the existing equipment.

3.2. Initial offering to external learners

The launch of the Industry 4.0 micro-credential at UBCO was, in part, a response to a call from the government of British Columbia in 2020 to support upskilling and reskilling the labour force in the province. Funding through the BC MAEST covered tuition costs for the learners, instructor and teaching assistant fees, and some capital costs (purchasing of lab infrastructure). The School of Engineering provided in-kind lab technician support and lab infrastructure. Due to restrictions on in-person gatherings stemming from the COVID-19 global pandemic, this initial offering was designed for online delivery. We decided that Programmable Logic Controllers (PLCs) would be the best Industry 4.0 topic as a significant portion would involve programming while the "hands-on" activities could be simulated using digital twin simulation. Modern PLCs also form the backbone of Industry 4.0 systems, enabling the use of smart devices in factory operations, distributed decision making, and data flow. The micro-credential was delivered to three cohorts over a two month period to learners external to UBC while a fourth cohort was integrated into a core Manufacturing Engineering course titled Industrial Automation. The micro-credential was thus offered to types of learners: those looking to upskill and/or reskill and to students within the Manufacturing Engineering degree program. The remainder of this subsection will describe the implementation that was offered to external learners.

Each cohort was run over three consecutive Saturdays at the beginning of 2021 which amounted to 20 hours of contact time with learners, although the total time commitment for learners was closer to 30 hours when time for studying and assessments is factored in. Sessions were seven hours in length and conducted over Zoom. Generally speaking, a session comprised of two 1.5 hour lectures which separated by two 2 hour lab activities. Although the lectures were conducive to delivery over Zoom, developing the lab activities for remote learners was challenging. Ideally, learners would develop and test their PLC programs on the physical MPS stations in the lab but this was not possible due to the remote delivery mode. Instead, we set up the UBCO lab computers for remote access. Once logged into the lab computers, learners had access to the software development environment (SDE) TIA Portal used to develop their PLC programs. For initial testing and validation, TIA Portal has a simulation plug-in called PLCSIM Advanced where a virtual PLC instance is created and the program from TIA Portal can be downloaded to it. For final testing, the CIROS digital twin simulation environment was used. In CIROS learners connected their virtual PLC to an OPC server called EzOPC to control CAD models of the physical MPS stations. The set-up is illustrated in Fig. 4.

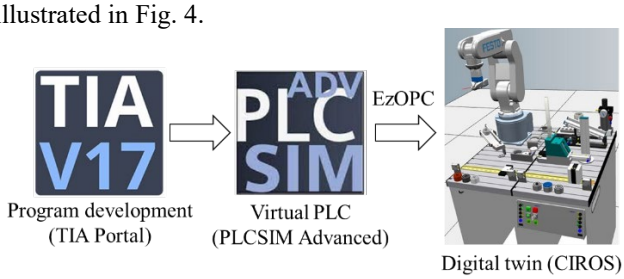
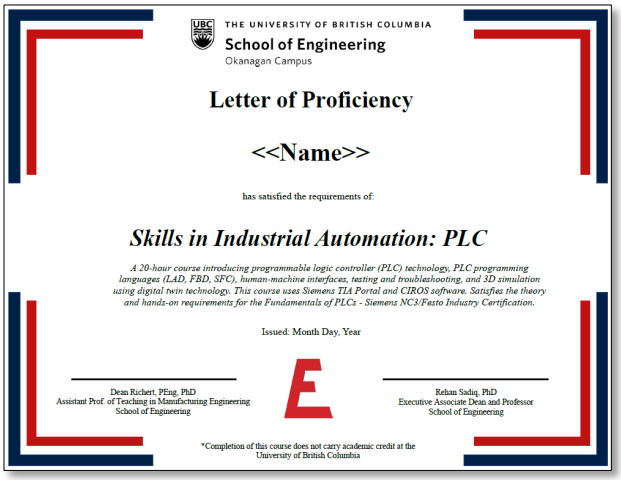


Fig. 4. Process used to by learners to develop and test PLC programs using digital twins.

As micro-credentials are competency based, learners were evaluated pass/fail rather than issued a numerical grade. Learners were assessed based on (i) post-lecture quizzes (six in total, one for each lecture), (ii) lab quizzes (twelve in total, two for each lab), and a (iii) final exam. To pass the micro-credential learners had to achieve a 70% average in each of the assessment categories (i)-(iii). Learners had two attempts at each quiz with the overall quiz grades being the highest of the two attempts. The final exam could be taken up to three times with the overall final exam grade being the average of the three attempts.


THE UNIVERSITY OF BRITISH COLUMBIA
School of Engineering
Okanagan Campus

Letter of Proficiency

<<Name>>

has satisfied the requirements of:

Skills in Industrial Automation: PLC

A 20-hour course introducing programmable logic controller (PLC) technology, PLC programming languages (LAD, FBD, SFC), human-machine interfaces, testing and troubleshooting, and 3D simulation using digital twin technology. This course uses Siemens TIA Portal and CIROS software. Satisfies the theory and hands-on requirements for the Fundamentals of PLCs - Siemens NC3/Festo Industry Certification.

Issued: Month Day, Year

Dean Richert, PEng, PhD
Assistant Prof. of Teaching in Manufacturing Engineering
School of Engineering

Rehan Sadiq, PhD
Executive Associate Dean and Professor
School of Engineering

*Completion of this course does not carry academic credit at the University of British Columbia

Fig. 5. UBCO Letter of Proficiency.

Upon successful completion of the micro-credential learners received a UBCO non-credit Letter of Proficiency (see Fig. 5) and were issued a digital badge through the Badgr platform. Digital badges can be easily shared through social media platforms such as LinkedIn.

The micro-credential was designed to cover all learning outcomes/competencies of the NC3 Fundamentals of PLCs (Siemens) certificate. Therefore, learners who earned the UBCO non-credit Letter of Proficiency were automatically eligible to take the NC3 exam if they chose. Since hands-on training with physical equipment is an integral requirement for NC3 certification, learners were initially issued a 1-year temporary certificate through a special arrangement with NC3 in light of COVID-19 restrictions. In August 2021, restrictions on in-person gatherings were lifted and learners were given the opportunity to come to UBCO campus and complete the hands-on training. Learners who participated in the in-person session were then issued a permanent NC3 certificate.

3.3. Integration into existing engineering program

In parallel with the initial offering to external learners, a fourth cohort of the micro-credential was integrated into course Industrial Automation, one of the core Manufacturing Engineering courses. In this course, the theory portion of the micro-credential was delivered during the scheduled one hour lecture times whereas students completed the lab activities during the scheduled two hour lab periods. The assessments and pass/fail criteria were as consistent as possible with the micro-credential offered to external learners, with some minor changes necessary based on the flow and scope of the course (the theory portion of the micro-credential occupied nine out of a total thirty-seven hours of instructor contact time). One of the main goals when integrating the micro-credential into Industrial Automation was to minimize, and ideally eliminate, any "extra" work for students beyond the requirements of the course. Because the micro-credential was integrated into an existing course, there was no cost to students to earn the Letter of Proficiency or the NC3 certification. The certification center, in this case UBCO, bore the financial burden through NC3 membership fees and the capital investment of Festo Didactic learning systems.

Following the initial offering of the micro-credential, we have integrated a number of other NC3 certificates into existing Manufacturing Engineering courses. Table X shows the mapping of certifications to courses.

3.4 Challenges

In addition to the challenges already discussed associated with developing and delivering a micro-credential during a global pandemic, there were a number of other challenges that were faced. Notably, access to IT resources such as remote lab computers, the Canvas LMS, network drives, and software licensing proved to be a complex problem since these systems were not designed with external learners in mind. Similarly, IT services and lab support were not available on weekends when the micro-credential was delivered. Continuing Professional Education at UBC Okanagan is an emerging and developing program and there are efforts to address these challenges at an institutional level.

4. Results and Discussion

The initial offering of this micro-credential ran at capacity for external learners (14 learners per cohort). The number of remote lab computers and software licenses limited the size of each cohort. 39 out of the 42, or 93%, external learners that registered for the micro-credential earned the UBCO Letter of Proficiency. 18 external learners chose to take the NC3 Fundamentals of PLCs (Siemens) exam and earned this certificate with a 100% pass rate. 13 external learners participated in the in-person session in August 2021. It is noteworthy that many of the external learners did not reside near the UBCO campus and thus could not realistically participate in the in-person sessions.

29 out of 34 students in the Industrial Automation course earned the UBCO Letter of Proficiency and, of those, 19 went on to earn the NC3 certificate.

Through this micro-credential, UBCO became the first NC3 member institution in Canada and continues to work with NC3 and Festo to improve and develop new Industry 4.0 certificates.

At the end of each offering a survey is sent asking learners to indicate their level of agreement to the following statements on a Likert scale:

- The hands-on session was an integral part of the micro-credential.
- I gained additional skills by participating in the hands-on session.
- There were some skills or concepts that I learned better from being hands-on with the equipment.
- I prefer the hybrid delivery model of this course (some components being online and some in-person) compared to fully online or fully in-person.
- The learning activities during the hands-on session were of an appropriate difficulty for my level of understanding of PLCs.
- The 3-hour hands-on session was an adequate amount of time to spend on the equipment given the earlier online/simulation sessions.
- The learning activities during the hands-on session were engaging and interesting.
- The NC3/Festo certification requirement was a motivator for participating in the hands-on session.

The survey results are used internally to improve the micro-credential program. Ethics approval to publish the survey results was not pursued for this work.

4.1. Alignment with guiding principles

In this section we evaluate the micro-credential relative to each of the guiding principles published by the BC MAEST.

Access – A silver-lining of running the micro-credential during a global pandemic is that learners from around the world including Nigeria, the UAE, and across Canada were able to participate. Thanks to remote access to the UBCO lab computers, learners only needed access to a stable internet connect and a computer with internet browsing capabilities. The pre-requisite for the micro-credential was "experience in at least one programming language" and it was left up to learners to self-assess their prior knowledge. In this way, learners from a diverse educational background were able to participate.

Quality – Quality was assured at a number of levels. A UBCO non-credit Letter of Proficiency is a UBCO Senate-defined credential which requires that learner presence is verified and completion and performance of tasks is assessed. Approval of a UBCO Letter of Proficiency is delegated to the faculty and, in this case, was approved by the School of Engineering Faculty Council. NC3 also enforces a robust quality control process for qualifying certification centers which includes train-the-trainer events, requirements on equipment used, standardized exams, and industry partnerships.

Relevance – Relevance includes alignment with labour market demands, government priorities, and institutional areas of expertise. The NC3 certification model ensures relevance to labour market demands through their strategic partnerships with industry. The micro-credential was well-aligned with government priorities since it was funded, in part, by a BC MAEST grant. Finally, the fact that the micro-credential was easily integrated into existing UBCO courses demonstrates that it was well aligned with existing UBCO expertise.

Collaboration & coordination – The micro-credential was delivered in partnership with instructors from Okanagan College, the Northern Alberta Institute of Technology (NAIT), and instructional support from Festo Didactic. The collaboration with NC3 opens up the possibility for transferability and laddering of credentials across institutions.

Employer and industry engagement – NC3 certifications are developed in partnership with global industry leaders such as Festo.

Clarity & transparency – A detailed syllabus which included the intended learning outcomes, delivery modes, assessment, pass/fail criteria, credentials issued, and prerequisite knowledge was made available when soliciting the course so that learners could make an informed decision on whether to participate. The UBCO Letter of Proficiency certificate, Badgr digital badge, and NC3 certificate all list the competencies attained by learners upon successful completion of the micro-credential. Potential employers presented with any of these credentials will clearly understand the competencies of the learner.

5. Conclusions and Future Work

In this paper, we have presented the design and implementation of an Industry 4.0 micro-credential program. UBCO, NC3, and Festo Didactic continue to work together to development Level 3 Industry 4.0 certifications. Future work will revolve around a number of areas including:

- Longitudinal tracking of learners and industry to measure the impact of the micro-credential,
- Refining the campus-wide framework and support for marketing and delivering micro-credentials to external learners,
- Evaluating and recognizing prior learning when admitting learners into or issuing micro-credentials,
- Considering micro-credentials for credit transfers,

- Establish a common registry of micro-credentials at the provincial, national, or international level to improve understanding, promote transferability, and reduce duplication of micro-credentials,
- Expanding to other industries such as HVAC, precision measurement, and data analytics,
- Develop micro-credentials targeted to secondary students (or earlier) to generate interest and reduce barriers to entry in STEM fields.

Future offerings of the micro-credential are planned to be delivered in a hybrid mode, with most lecture content delivered asynchronously by video while labs will be in-person. The hands-on labs of the micro-credential are deemed essential for learners to gain the required competencies yet these also pose a bottleneck in terms of scalability. With the current infrastructure at UBC Okanagan, 18 learners can participate in the lab activities at a time.

As mentioned, funding from the BC MAEST covered the cost of tuition for all learners. For the sustainability of the program, an appropriate tuition model must be determined. Comparable programs at other Canadian institutes charge around CAD 1,500 per learner at the time of writing.

Acknowledgements

The authors would like to acknowledge generous funding from the BC MAEST which was used towards instructor fees, equipment purchases, instructor training, technical support, and administrative costs. This work would not have been possible without the support of Dr. Michelle Lamberson, Director of Flexible Learning Special Projects in the Office of the Provost and Vice-President, Academic at UBCs Okanagan campus who liaised with the BC MAEST and was instrumental in coordinating campus-wide IT and administrative support. Finally, we would like to acknowledge Dr. Homayoun Najjaran, Professor at University of Victoria, who had the vision, secured funding, and provided consultation throughout the design of this micro-credential program.

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