Implementing the Mechanisms to Lessen the Talent Gap in Advanced Manufacturing

An NSF/ATE Project DUE 1902379

EVALUATION REPORT

Year 3: February 1, 2021 to October, 2022

Presented to:

Richard Hendricks, Principal Investigator
Pennsylvania College of Technology
One College Avenue
Williamsport, PA 17701-5799

Prepared by The Allison Group
Seattle, Washington
206-525-7175 tbailey@theallisongroup.com

Date: September 2022

Acknowledgments

Co-Principal Investigator Bradley Webb was instrumental in implementing the evaluation for year three of the grant. He met with the external evaluator on a monthly basis to implement the detailed evaluation plan and provide subject matter expert input into the development of surveys. He also compiled the data and information for the evaluation.

PI Richard Hendricks, Co-PI Webb and the project team at Pennsylvania College of Technology produced high quality project documentation that provided an accurate summary of the project's third year of operation.

This material is based upon work supported by the National Science Foundation under grant number 1902379. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

List of Tables

List of Figures

List of Acronyms

19MAC	Implementing the Mechanisms to Lessen the Talent Gap in Advanced Manufacturing (Machining Grant 2019)
ATE	Advanced Technological Education
CAD/CAM	Computer Aided Design/Computer Aided Manufacturing
CNC	Computer Numerical Control
DUE	Division of Undergraduate Education
GD&T	Geometric Dimensioning and Tolerancing
MET	Manufacturing Engineering Technology
NSF	National Science Foundation
PCT	Pennsylvania College of Technology
PI	Principal Investigator
RSO	Required Student Outcomes
SLS	Selective Laser Sintering
TAG	The Allison Group

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The Implementing the Mechanisms to Lessen the Talent Gap in Advanced Manufacturing Project, known as the machining grant 2019 (19MAC), received a three-year award ($591,924.00) from NSF ATE (DUE 1902379) in May 2019, with the grant ending April 30, 2022. In July 2019, the grant was awarded a supplemental to send faculty and students on a trip to Germany to study precision machining. The trip was delayed due to the COVID-19 pandemic, but the project was able to complete the trip in the summer of 2022 after receiving a no-cost extension. The grant now ends October 31, 2022. Pennsylvania College of Technology in Williamsport, PA is the 19MAC Project fiscal agent.

The 19MAC project seeks to increase the number of qualified workers in advanced manufacturing such that it will combat the growing skills gap between the entry-level workforce and graduates of secondary school and community colleges. Over the three years of the grant, the project realigned Penn College's manufacturing curriculum to embed more technologically sophisticated skills and increase enrollment in Penn College's CNC certificate program and the two-year AAS degrees in Machine Tool Technology and Automated Manufacturing. The grant supported the increased placement of highly qualified graduates into regional industry positions.

In year three, the grant team, under the leadership of Co-PI Bradley Webb, achieved its goals for the year, with minor delays due to the pandemic which impacted enrollment. Highlights include:

- A trip to Germany for students and college faculty to observe precision machining in the German education system.
- The first graduates of the new CNC certificate program.
- The approval of the Apprenticeship Technology Degree.
- Revisions to multiple machining programs and courses.
- Increased enrollment in the AAS and BS programs.
- A $1 million grant from the HAAS Foundation for additional multi-axis machining and renovation to the advanced manufacturing lab.
- Conducting one Teacher Externship program.

Despite challenges from the COVID-19 pandemic, the team was able to leverage donations, grants and the CNC ATE grant to impact not only the advanced manufacturing program but to spread ideas to other programs.

Co-PI Webb has done an excellent job in securing the materials needed for labs to support new and modified curriculum and providing the only Selective Laser Sintering (SLS) technology available for two-year AAS students. The grant team was able to dispel myths that advanced manufacturing is a dangerous career though outreach and dissemination of information about the education path and career.

INTRODUCTION

The Implementing the Mechanisms to Lessen the Talent Gap in Advanced Manufacturing Project, known as the machining grant 2019 (19MAC), received a three-year award ($591,924.00) from NSF ATE (DUE 1902379) in May 2019, with the grant ending April 30, 2022. In July 2019, the grant was awarded a supplemental to send faculty and students on a trip to Germany to study precision machining. The trip was delayed due to the COVID-19 pandemic, but the project was able to complete the trip in the summer of 2022 after receiving a no-cost extension. The grant now ends October 31, 2022. Pennsylvania College of Technology in Williamsport, PA is the 19MAC Project fiscal agent.

The 19MAC project seeks to increase the number of qualified workers in advanced manufacturing to combat the growing skills gap between the entry-level workforce and graduates of secondary school and community colleges. During the three years of the grant, the project realigned Penn College's manufacturing curriculum to embed more technologically sophisticated skills, created a new CNC certificate program and increased enrollment in Penn College's two-year AAS degrees in Machine Tool Technology and Automated Manufacturing. The grant also supported the increased placement of highly qualified graduates into regional industry positions.

This report covers year three of the 19MAC project grant, for the period February1, 2021 to October 31, 2022. The evaluator and Co-PI Webb met monthly to stay current with the implementation of the evaluation and to keep the evaluator informed of grant activities. The evaluation covers information from those meetings, combined with findings from the data gathered through surveys and project documentation. A summary of the approach to evaluation is found in Appendix 1.

Project Goals and Objectives

The project's two stated goals with associated objectives.

Goal 1: Realign Penn College's manufacturing curriculum to embed more technologically sophisticated skills.

Objective 1.1: By the end of Year 1, a one-year CNC certificate program is developed that includes technologically advanced skills needed by industry, as evidenced by updated and revised required student outcomes (RSOs) and course descriptions that align with new equipment and technology.

Objective 1.2: By the end of Year 2, revise the AAS curricula in Machine Tool Technology and Automated Manufacturing to cover technologically advanced skills, as evidenced by updated and revised required student outcomes (RSOs) and course descriptions that align with new equipment and technology.

Objective 1.3: By the end of Year 2, create alignment between the CNC certificate program and the AAS programs in Machine Tool Technology and Automated Manufacturing, as indicated by 6 out of 7 major certificate courses transferring over to the Machine Tool Technology AAS program and 7 out of 7 major courses transferring over to the Automated Manufacturing AAS program.

Objective 1.4: 100% of students in the CNC certificate and AAS programs receive hands-on training on the new CNC multi-axis machining centers and coordinate measuring machine.

Objective 1.5: Penn College has in place a formal process to award credits for completion of an approved apprenticeship program.

Goal 2: Increase enrollment in Penn College's CNC certificate program and the two-year AAS degrees in Machine Tool Technology and Automated Manufacturing, and place graduates into industry positions.

Objective 2.1: 15 students enroll annually in the CNC certificate program and 20 students in the AAS programs by the end of Year 3.

Objective 2.2: 25% of students graduating from the CNC certificate program enter one of the two AAS programs.

Objective 2.3: 90% of students completing the CNC certificate or one of the two AAS programs are placed in a manufacturing position.

Purpose and Design of the External Evaluation

The Co-PI and evaluator collaborated to develop a detailed evaluation plan for year three that produced evaluative data that minimized the amount of overlap between the annual report and the evaluation report. This was accomplished by focusing the evaluation report on outcomes and impacts, and the annual report on activities and results. These efforts resulted in the following evaluative questions.

1. To what degree was the project implemented as planned? What successes were achieved and what challenges were addressed?
2. To what extent did the project activities increase the enrollment of students in technologically advanced CNC programs? Of underrepresented populations in technologically advanced CNC programs?
3. To what extent did the project's work lead to improvement of training and education of the advanced manufacturing technician workforce?

Table 1 below describes the evaluation plan and data collection process to gather evidence to address the evaluative questions.

Indicator	Data Sources & Methods	Analysis
Evaluation Question 1. To what degree was the project implemented as planned? What successes were achieved and what challenges were addressed?		
Degree of match between plan and execution of the development and revision of curriculum to align with industry needs	Document review to compare actual process with plan	Comparative analysis of project's methodologies and strategies to develop, revise and align curriculum, revise AAS degree programs, recruit high school students to the advanced manufacturing program and award credit for apprenticeships
Degree of match between plan and execution of revision of AAS degree programs		
Degree of match between plan and execution of recruiting efforts		
Degree of match between plan and execution of the award of credit for apprenticeship		
Feedback from professional development participants on the quality and utility of the workshops	Pre, post and delayed post surveys of faculty participants	Descriptive statistics, including means, top-two box scores and trend analysis; Thematic coding to determine factors that increase or suppress the impact of professional development on classroom practice regarding new technology
Evaluation Question 2. To what extent did the project activities increase the enrollment of students in technologically advanced CNC programs? Of underrepresented populations in technologically advanced CNC programs?		
Number of students and percentage from underrepresented populations enrolled in the Machine Tool Technology and Automated Manufacturing AAS degree programs, and the new CNC Certificate	Query of PCT database for current year; for prior years to establish a baseline	Descriptive statistics, both aggregated and disaggregated by demographic characteristics; comparison of data before and after the start of the project
Feedback on the quality and utility of recruiting activities to include teacher externships and Student Symposiums	Pre, post and delayed post surveys of event participants to include evaluation of learning and change in attitude and perception toward manufacturing workplaces and careers	Descriptive statistics, including means, top-two box scores; Thematic coding to determine factors that increase or suppress the impact of the recruiting events on enrollment

Indicator	Data Sources & Methods	Analysis
Question 3. To what extent did the project's work lead to improvement of training and education of the advanced manufacturing technician workforce?		
Opinions of industry advisors on degree of alignment of new curriculum and degree programs with their workforce needs	Surveys and/or interviews with industry advisors; project documentation regarding strength of relationship with industry	Descriptive statistics, including means and top-two box scores; Thematic coding to identify factors that contributed to the degree of alignment reported by industry advisors
Degree of improvement in classroom content of advanced manufacturing programs at PCT	Surveys and/or interviews with faculty who teach the new CNC and AM equipment content	Descriptive statistics, including means, top-two box scores; Thematic coding to determine factors that increase or suppress the impact on classrooms
Student learning and perceptions of preparation for the advanced manufacturing technician workforce	Surveys and/or interviews with faculty regarding their observation of impact of the new curriculum on students; surveys of students regarding self-efficacy and plans regarding advanced manufacturing employment	Descriptive statistics, including means, top-two box scores; Thematic coding to determine factors that increase or suppress the impact on students

Table 1: Overview of Evaluation Plan

In year three, the external evaluator and Co-PI met in accordance with a regular meeting schedule to update the evaluator on the project activities, develop survey instruments and implement a detailed data gathering plan and reporting schedule.

Additionally, the external evaluator, in collaboration with Co-PI Webb, updated the survey to obtain feedback on classroom teaching of the new curriculum and the prior existing curriculum. This five-item instrument asked about the impact on students and the quality of the curriculum. The survey was conducted in December 2021 and August 2022 and was completed by three of the ten faculty involved. Again this year, the response rate was not as hoped. However, a 30% response rate and the collection of faculty input on ten sections during the COVID-19 pandemic is acceptable.

In addition, the external evaluator updated pre-and-post surveys for the Externship participants. The response rates for these surveys were outstanding. All (100%) of the participants completed the pre-survey and 14 of the 17 participants completed the post survey (82.3%). The pre-survey consisted of three questions, asking about level of knowledge and demographics. The post-survey had 13 questions that asked about level of knowledge, how participant planned to implement their learning, and quality of the event.

Lastly, the evaluator developed surveys for the faculty and students who went on the trip to Germany. The faculty survey consisted of two questions that asked about how they will use what they learned on the site visits, observations of the German system, and comments about the trip overall. The student survey asked about the most exciting things they learned, the advantages and disadvantages of the German and U.S. systems, and impacts of the trip on their career choices. All seven (100%) of the students who went on the trip completed the survey, producing an outstanding response rate.

The external evaluator also provided an Evaluation Preparation Questionnaire and Outreach and Dissemination Worksheet for the project to use in compiling the data for the evaluation report.

The 19MAC Project documentation was provided with respect to major initiatives, accomplishments and challenges. The results of the project documentation and the meetings with the project team were reviewed, analyzed and then discussed with the Co-PI Webb. The larger themes that emerged are described in this report.

QUESTION 1: To what degree was the project implemented as planned? What successes were achieved and what challenges were addressed?

Co-PI Webb has done an excellent job working challenges in the third year of the Penn College 19MAC grant. For the SLS Additive Manufacturing component, the team initially selected a Formlabs Fuse 1 machine. However, delivery dates continued to be pushed out until the company said their machines would be delivered beginning in February 2021, almost three years after the initial model demonstration when the machine was selected by the college. The grant team anticipated that backorders will push delivery even further into 2022.

During this lag time, the grant team pursued another option and selected the Sinterit Lisa machine that had the same functionality with identical nylon powder as the Fuse 1 and was immediately available for a similar price. The machine was delivered in September 2020 and installed in the Metrology Lab.

Following delivery, a professional development course was created and offered free to faculty. Two instructors took the course, which included taking a sample part file and working through the complete build process; cleaning and restarting the machine for the next job; and reviewing details on safety issues of powdered plastic. All course materials including lecture slides, software, sample part files, digital copies of user manuals and other resources were placed on a cloud drive for future access. Faculty also connected with technical support personnel at the Sinterit factory, and as other faculty become interested in using the Sinterit Lisa, the cloud files can be freely shared for study and reuse.

The new machine to be used in a course that the two trained faculty taught in the Spring 2021 semester. These faculty are also qualified to train other faculty as needed. Faculty contacts with industry allow for insight into industry developments that impact new applications for use in the Mechatronics AAS classes and Fixtures and Fabrication class.

Activities

The activities in Table 2 below reflect the status of tasks at the completion of the third year of the grant.

	Y1	Y2	Y3	Status
Prepare proposal for certificate	X			Done
Submit proposal and obtain approval	X			Done
Implement CNC certificate		X		Done
Prepare proposal for revised AAS degree programs		X		Done
Submit proposal and obtain approval		X		Done
Implement new AAS degrees		X		Done
Research awarding credit for apprenticeship			X	Done
Implement awarding credit for apprenticeship			X	Done
Select student project for symposium	X	X*	X**	Done
Outreach to high schools for student participants in symposium day	X	X*	X**	Done
Implement symposium	X	X*	X**	Done
Develop structure for teacher Externship program for each year	X	X	X	Done
Outreach to high schools for teacher participants in Externship program	X	X	X	Done
Implement Externship event	X***	X	X	Done
Review lesson plans/instruction in the high schools		X	X	Done
Disseminate lesson plans		X	X	Done

Table 2: Activity Status Chart

*Note: The on-campus student symposium was cancelled due to COVID-19 and the need to institute health and safety measures. **2021 Symposium was virtual. ***The project conducted one Externship in year two and one in year three. Originally three Externships (10 participants in each summer) were planned, but given the timing of the award, an Externship in summer 2019 was not possible. As such, the cap was raised to 15 per Externship, so the project impacted the same number of teachers in a shorter timeframe.

The program activities for year three were met, including the symposium which was cancelled year two due to the COVID-19 pandemic, and was conducted virtually in year three. (See Notes, above.) Additionally, international travel to Germany to study and learn about methods of manufacturing and educational training was postponed from year 2 but took place in year 3. This latter opportunity was developed through supplemental funding for educational study in Germany, a world leader in CNC technology, and the home of the German Vocational Training System.

Revisions to all machining programs were concluded in the spring of 2021 for fall 2021 completion, and details on these activities are addressed in Question 3.

Externship Program

The project team and the college worked collaboratively to host a summer Externship program in July 2021 for 17 educators, recruiting technology teachers and guidance counselors from high schools across Pennsylvania. The one-week program showcased mills, lathes, prototyping, careers and on-the-job environments at advanced manufacturing companies. Penn College currently has dual enrollment programs with area high schools, and this new training will increase opportunities to expand dual enrollment in manufacturing, as well as expand opportunities for recruitment of high school students to the program. In addition, this activity could help prepare high school instructors to talk about careers in manufacturing with more detail and a better understanding of today's advanced manufacturing sector. For the externship, 19MAC concentrated on counselors and non-technology teachers (history, science, special education, etc.). This allowed the project to expose these educators to careers they had not previously known existed. For the externship, 19MAC concentrated on counselors and non-technology teachers (history, science, special education, etc.). This allowed the project to expose these educators to careers they had not previously known existed.

Pennsylvania teachers who participated earned continuing education credits. They also benefitted from connections with industry, learned about manufacturing processes, gained hands-on experience with using machining equipment, were provided with sample lesson plans, and were required to develop a project that links the content learned on the PCT campus to their lesson plans at their home school. The teachers were also compensated for their week on campus with a stipend and the continuing education hours mentioned above (required for teachers in Pennsylvania).

The program was so successful, that participants recommended that the program be offered to middle school and high school parents. Additionally, this externship event has been adapted for the aviation program. This program was also used to secure a PASmart Grant (offered by the state of Pennsylvania), where they secured over $300K in funding to focus on manufacturing and construction workforce education.

Figure 1 shows the Pennsylvania College of Technology's Penn CNC website (www.pct.edu/skillsgap), which links to information on the Externship Camp for educators.

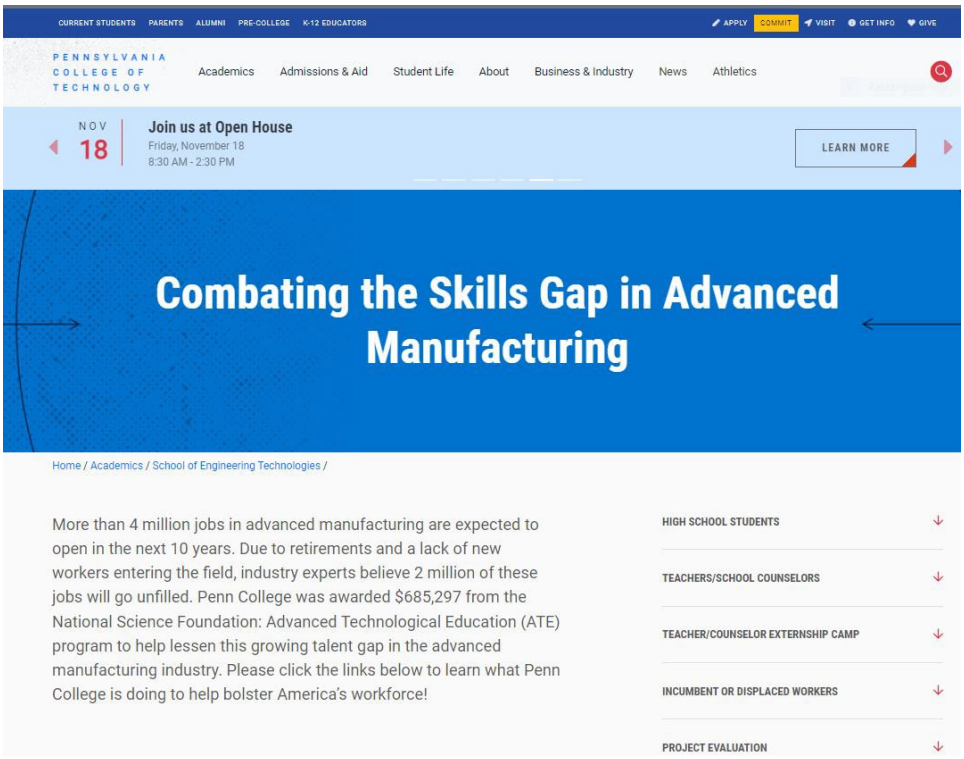


Figure 1: Penn CNC Website Information

Figure 2 shows a list of educators who participated in the camp and resource information they created following it. This information is available for other educators to use in their own school settings. The resources include lesson plans and slide presentations that can be used to show how the skills gap in advanced manufacturing can be addressed by the educational path at Pennsylvania Technical College.

Participants in the Externship Camp show in their lesson plans how they are using information they learned with students and parents. For example, one high school teacher showed his students a video on the Mars Rover, and then they made their own helicopters. They then discussed why the helicopter floated faster to the ground than a flat sheet of paper. Links for other resources are also included in the lesson plans.

Additionally, general resources are listed with links on the Externship Camp section, including a slide presentation on Manufacturing Engineering at PCT, a list of resource links and how to use them, and a slide presentation on the Penn College CNC program and busting the myths surrounding advanced manufacturing.

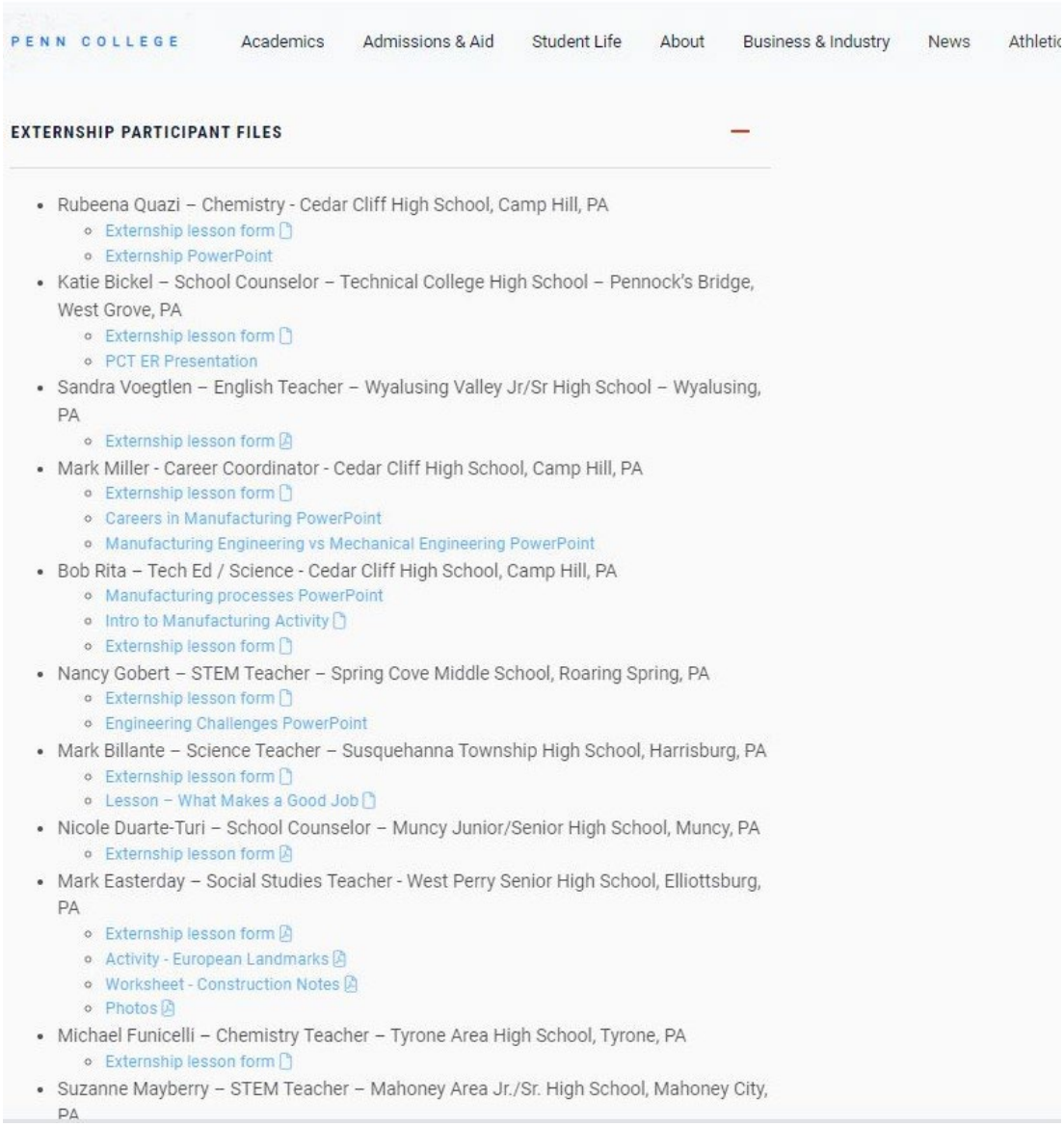


Figure 2: Externship Resources for Use by Educators

Participants were asked to rate the overall event, and all but one rated it good to excellent. (This person rated it adequate.) This rating indicates the training was a success and met the expectations of the participants. The choices were:

- Excellent – exceeded my needs and expectations
- Good – met my needs and expectations
- Adequate – about typical for an institute of this type
- Marginal – didn't help me very much, I was hoping for something else
- Poor – my time was wasted

Participants were asked to rate the quality of different components of the Externship. The survey used a four-point Likert scale. Ratings were assigned a numerical value from 1 to 4: 1 – Poor; 2 – Fair; 3 – Good; 4 – Excellent

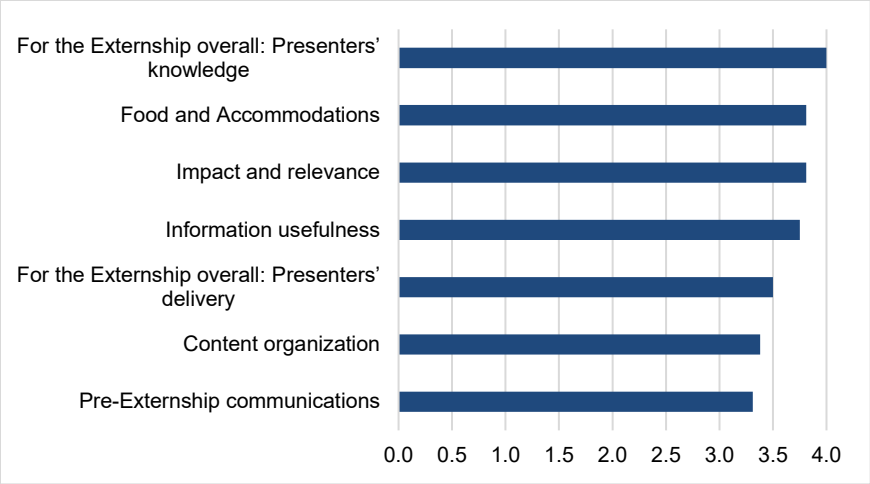


Figure 3: Quality of Externship Components (weighted average), n=16

As can be seen from Figure 3, all components were rated between 3.3 and 4.0 on a 4-point scale, which are excellent marks for a session ranging from content to food. The highest score of a 4.0 was for the presenters' knowledge. Three components clustered together at around 3.8 were food and accommodation, impact and relevance and information usefulness. Organizers of the event are given kudos for having a workshop that rated impact and relevance and information usefulness between good and excellent. The purpose of these educator trainings is to prepare them for sharing this information in the classroom, with other teachers and with parents. See Question 3 for how the educators saw their knowledge improve from participating in this camp.

When providing comments on the camp, the following three quotes show that the goal of this workshop reached its target:

> *"Great week. Looking forward to sharing this information with our stake holders."*
>
> *"I was expecting to learn more about manufacturing, but I learned so much more. This externship exceeded my expectations! I will be taking the information I learned back to my district, to share with admin, teachers, students, family, and community."*
>
> *"This was an amazing experience! If I was younger, I'd switch careers."*

Several participants mentioned the Lycoming Engines tour, where they were able to observe the equipment in use in person. Hands-on experiences received multiple mentions.

Participants offered suggestions on how the Externship could be improved. These included:

- More interaction with students who attend the school
- More examples of how the machines work
- Access to some of the labs in the evening
- Have students involved in the process
- Extend to two weeks

The grant team and college is commended for conducting an event with high quality ratings that produced resource materials not only for the attendees but also made available to other educators through their website. Based upon comments from the surveys, participants left the event excited about advanced manufacturing as a career and the educational path to get there. As this event is broadened to other

participants such as teachers in middle school and parents, a survey of these participants would yield enhanced information on how the field is perceived and if these events lead to an increase in enrollment in the advanced manufacturing program.

Planning for Sustainability

This project provides many elements that support sustainability. First, the newly purchased equipment will continue to positively impact current student classes and allow students to try new techniques in a safer setting for years to come.

Second, the grant has elevated engagement in the department and empowered the faculty to offer more ideas, help write curriculum, and support new activities. Creating a positive work environment that is engaged, collaborative, and mutually supportive will provide benefits to the department and the college long after the grant ends.

The new and revised courses have been added to the official curriculum, ensuring the concepts are sustained in the educational offerings.

Third, the teacher Externship event provided needed continuing education credits, along with exposure to industrial processes, hands-on experience, and connections with businesses. Details about this event are detailed in the Externship Program section, above.

Another boon to sustainability came in the form donations to be used for equipment and lab upgrades. In 2019, a significant gift of $1 million from a college alumnus, the largest donation in the history of Pennsylvania College of Technology, allowed plans developed from the grant to grow exponentially. Larry Ward's donation was used for the updating of the 14,299 square-foot lab (fresh lighting, flooring and fixtures) and more than 25 new machines to supplement the four machines purchased through grant funds. This donation allows an acceleration of curricular revisions due to the equipment that facilitates teaching advanced CNC. The grant team reports that the updated facility, called the Larry A. Ward Machining Technologies Center, supports making changes that are long lasting and beneficial.

In this third year of the grant, the HAAS Foundation donated another $1 million (matched by Pennsylvania College of Technology) to purchase multi-axis machining equipment and renovations to the advanced manufacturing lab. This donation will facilitate future curricular offerings in multi-axis machining.

The grant is to be commended for improving the advanced manufacturing machining program through faculty training, upgrades to courses and securing donations that allow for new equipment in the lab and upgrades to the lab facilities.

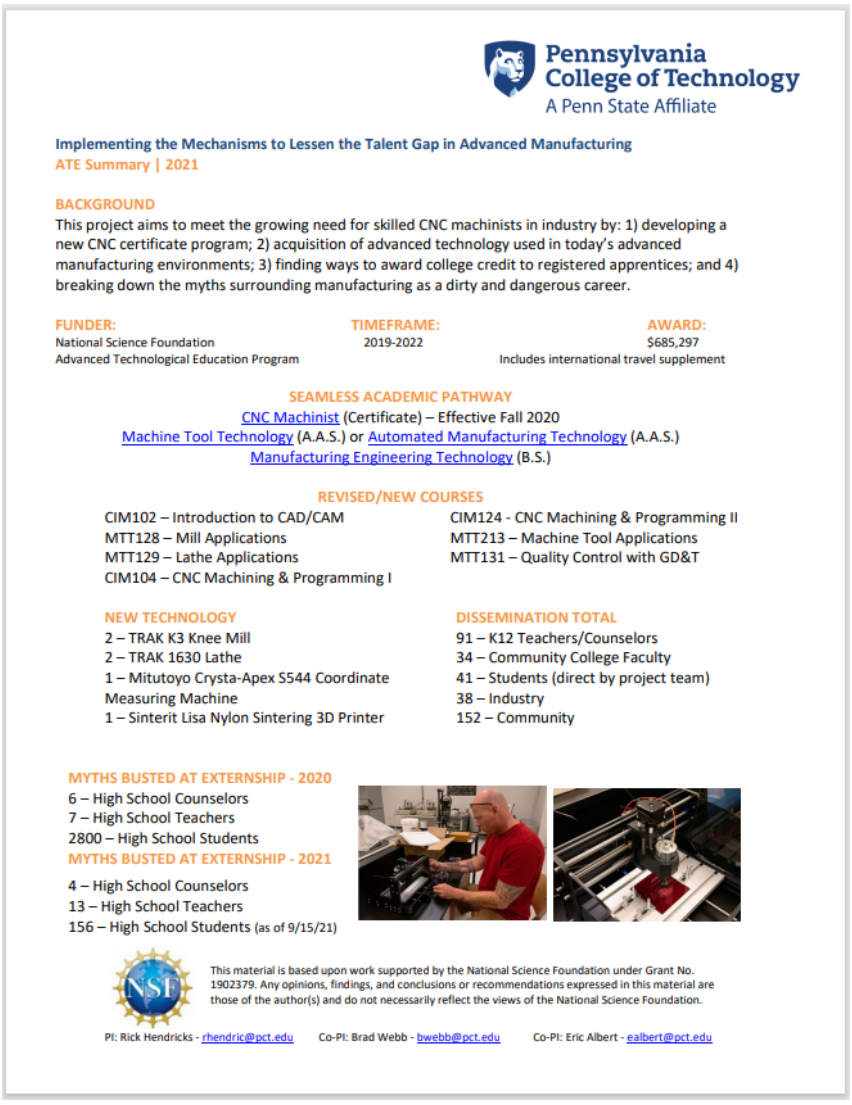
Dissemination

During the third year of the grant, the team was faced with a challenge of disseminating information and results of its program while navigating health and safety protocols established because of COVID-19. This third year made more progress than the prior year which had two major events cancelled – symposium and international study abroad. These two events were able to be held in year three. Additionally, the grant team was able to reach out to high school and college students and faculty and businesses through presentations at conferences, Externship training, other training sessions and a manufacturing advisory board meeting.

The grant team disseminated information about this grant and the grant outcomes to the following communities from 9 unique activities:

- K-12 teachers and counselors – 59
- Two-year faculty – 83
- Students – 1,153
- Industry- 51

The grant shared highlights of its program at the October 2021 ATE PI Conference in Washington, D.C., in the ATE Connects live video sharing session, where other attendees can learn about programs, share ideas and form contacts for potential future collaborations. The conference is held yearly for NSF ATE projects and center teams. A 90-second video presentation ran on a continuous loop for participants to learn about program highlights, and the grant team also prepared a one-page handout showing an executive summary of the grant and its accomplishments. (See Figure 4.)



Pennsylvania College of Technology
A Penn State Affiliate

Implementing the Mechanisms to Lessen the Talent Gap in Advanced Manufacturing
ATE Summary | 2021

BACKGROUND
This project aims to meet the growing need for skilled CNC machinists in industry by: 1) developing a new CNC certificate program; 2) acquisition of advanced technology used in today's advanced manufacturing environments; 3) finding ways to award college credit to registered apprentices; and 4) breaking down the myths surrounding manufacturing as a dirty and dangerous career.

FUNDER: National Science Foundation, Advanced Technological Education Program
TIMEFRAME: 2019-2022
AWARD: $685,297, Includes international travel supplement

SEAMLESS ACADEMIC PATHWAY
CNC Machinist (Certificate) – Effective Fall 2020
Machine Tool Technology (A.A.S.) or Automated Manufacturing Technology (A.A.S.)
Manufacturing Engineering Technology (B.S.)

REVISED/NEW COURSES
CIM102 – Introduction to CAD/CAM
MTT128 – Mill Applications
MTT129 – Lathe Applications
CIM104 – CNC Machining & Programming I
CIM124 - CNC Machining & Programming II
MTT213 – Machine Tool Applications
MTT131 – Quality Control with GD&T

NEW TECHNOLOGY
2 – TRAK K3 Knee Mill
2 – TRAK 1630 Lathe
1 – Mitutoyo Crysta-Apex S544 Coordinate Measuring Machine
1 – Sinterit Lisa Nylon Sintering 3D Printer

DISSEMINATION TOTAL
91 – K12 Teachers/Counselors
34 – Community College Faculty
41 – Students (direct by project team)
38 – Industry
152 – Community

MYTHS BUSTED AT EXTERNSHIP - 2020
6 – High School Counselors
7 – High School Teachers
2800 – High School Students

MYTHS BUSTED AT EXTERNSHIP - 2021
4 – High School Counselors
13 – High School Teachers
156 – High School Students (as of 9/15/21)

This material is based upon work supported by the National Science Foundation under Grant No. 1902379. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

PI: Rick Hendricks - rhendric@pct.edu Co-PI: Brad Webb - bwebb@pct.edu Co-PI: Eric Albert - ealbert@pct.edu

Figure 4: Penn CNC Handout for NSF ATE Conference

Additionally, the grant has a website related to the project to disseminate new developments to the community (See Figures 1 and 2.). Since Pennsylvania College of Technology is the only college offering the SLS technology to 2-year AAS students, this website has the potential to disseminate learnings to other institutions who might want to start this or a similar program.

After the success of the Externship Camp for faculty (see earlier Externship Program section), faculty suggested crafting a similar experience for middle and high school parents. Receiving a grant from the EQT Foundation, the college hosted two weekend events in June 2022 for parents, attended by 22 parents and students. Highlights from the weekend event included manufacturing, diesel technology and plastics careers. Hands-on experience on the machines in the lab were featured, along with information about these careers. Branching out from these events, the college hosted an Aviation Externship in July 2022 attended by 15 teachers, taught by Co-PI Webb.

Industry Collaboration

19MAC engaged with a variety of industries to get input on the grant program, and industry contacts supported the program through the sharing of cloud files for the new equipment, Sinterit Lisa; the alumnus donation as previously reported; grant from the HAAS Foundation and advisory board session. PI Hendricks represented the grant program at two meetings in the spring of 2022 of the Jersey Shore Area School District Advisory Board meeting for Manufacturing, attended by 34 participants from the community.

International Study Trip to Germany

As mentioned above, the project identified an unexpected opportunity and submitted a supplemental proposal to fund an educational study visit to Germany. On the 16-day trip, 7 students and 2 faculty chaperones received training at the Eckert International Vocational School, a leader in German Vocational Training, and met with numerous companies that are on the cutting edge of CNC and automation technology, such as Voith, Siemens, and Porsche. The trip allowed the faculty to experience the dual-vocational system in action and give students exposure to a tailored German Industrial Training designed specifically for the group. The faculty participated in a workshop on the dual vocational education system and had access to Eckert faculty and the program administrators for in-depth discussions. Eckert managed and led the training, provided educational materials, and arranged some company visits.

After the trip, students and educators were asked for feedback on their experiences. (Student feedback is being reported in Question 3.)

Faculty reported several insights including similarities between training content in Germany and PCT, differences including German government mandates regarding education paths, and suggestions for any future trip.

Similarities:

> *"The trip showed us that our techniques and strategies are very similar to theirs proving that two programs on different sides of the world can come to the same conclusions."*
>
> *"Incredible opportunity to visit a college very similar to ours and see how they provide instruction on the same topics. Exposure to a different culture was a truly transformational experience for our students. Excellent tours of a variety of manufacturers and another technical college. Great sightseeing tours in neighboring villages."*

German education program:

> *"Stronger and more focused **strategies** of guiding high school students into **career paths at an earlier age**. Germany provides dual enrollment, co-ops, internships to students with corporations, health care systems, and various professional companies and organizations to **begin training them while still in high school.** This **dual enrollment system is partially funded by the German government** to provide financial relief and to assure a steady flow of future professionals, tradespeople, etc."*
>
> *"The **country also mandates country wide policies** when it comes to the sharing of **new educational curriculum, training, etc.** so that all regions and future employees have the same opportunities for future professions."*

Suggestion/Lesson Learned:

> *"Our students already had most of the level of training we received. Next time we need to communicate better the level of education our students have prior to scheduling each session."*

Faculty praised the opportunity to visit a different college with a similar program, exposure to cultural differences and tours of varied manufacturers. The study trip provided valuable experiences that faculty cannot receive locally. The grant staff is to be commended for securing supplemental funds to finance the trip and to work around changes occurring because of the delay from pandemic obstacles.

QUESTION 2: To what extent did the project activities increase the enrollment of students in technologically advanced CNC programs? Of underrepresented populations in technologically advanced CNC programs?

The new curriculum was implemented in the Fall 2020, and enrollment in the classes was consistently 24 or 25 in each course. Enrollment data collected by the college's Institutional Research Office revealed that the majority of students in the program are white males with one female and three Hispanic males taking the courses. One of the strategies for improving diversity was the exposure of teachers and counselors in the summer Externship program to the advanced manufacturing field as a viable one for their students. Numbers for 2021-2022 only include Fall of 2021 and Spring 2022. Table 3, below, shows the enrollment numbers of female students and non-white students. Note: These non-white students are also First-Generation college attendees from their families.

The Fall of 2021 showed an uptick of non-white/First-Generation students, and the same level of female students. There is no spring 2021 number to compare with the 2022 enrollment number, so the lower number may be normal for a dip from fall to spring. (See Table 3.)

Fall/Spring Enrollments	2018	2019	2020	2021	2022
Female	3	1	1	1	0
Non-White	9	12	14	19	7

Table 3: Enrollment numbers for courses in 2018-2022

Since the Fall of 2020 is the first semester to offer new and revised courses, comparing to the prior two years of fall enrollments may provide a basis for comparing future enrollment trends. Table 4 shows the breakdown of low-income students who enrolled in classes from fall semesters in 2018, 2019, 2020 and 2021. (Students coming from a low-income population segment can be another indicator of underserved

populations, along with gender and race.) The percent of total enrollment of these students increased in 2021, compared to the Fall of 2020. However, due to the COVID-19 pandemic, these 2020 and 2021 students may have been impacted by the need to work over the ability to attend classes and/or the ability to access computers and internet to help them navigate changes in the college protocols and course offerings. This may explain the lower percentages from prior fall semesters. (One of the strategies of the grant is to provide opportunities to students from underrepresented demographics who would not normally enter this career field.) See Table 4.

Fall Enrollments	2018	2019	2020	2021
Low Income Enrollment	25	29	22	33
Total Enrollment	75	88	98	128
Percent Low Income Enrollment	33%	33%	22%	26%

Table 4: Low Income Student Enrollment comparing Fall Semesters 2018-2021

A similar comparison can be made with students who are the First Generation in their families to attend college. These students are often non-white but may or may not be persons of color. This trend differs from that of low-income students, as their percent of total enrollment increased from last year and is on par with the year prior to the start of the pandemic. The college may want to watch these enrollment trends in the future and consider surveying these students to determine what factors impacted their decisions to enroll in the program. (See Table 5.)

Fall Enrollments	2018	2019	2020	2021
First Generation Enrollment	22	37	36	53
Total Enrollment	75	88	98	128
Percent First Generation Enrollment	29%	42%	37%	41%

Table 5: First Generation Student Enrollment comparing Fall Semesters 2018-2021

Note: These enrollment tables include students who took more than one class in the program in the Fall Semester (duplicated headcounts).

Three students have graduated with the new CNC certificate, and four students are enrolled in the program to pursue the certificate as of August 2022.

QUESTION 3: To what extent did the project's work lead to improvement of training and education of the advanced manufacturing technician workforce?

Educator Knowledge and Skills

Prior to the Externship Camp, conducted in the summer of 2021, participants were asked to indicate their level of knowledge and skills in advanced manufacturing topics. The same question was posed to the participants after the camp to determine the effectiveness of the activity. To put these ratings in context, it should be noted that there were 12 high school teachers and three high school counselors taking this workshop. Their gender breakdown included 11 females and 6 males. Sixteen were Caucasian and one was Asian.

The survey used a five-point Likert scale. Ratings were assigned a numerical value from 1 to 5:

1 – No Knowledge
2 – Beginner (Has some knowledge or basic experience)
3 – Proficient (Can use at a satisfactory level)
4 – Advanced (Can use better than most)
5 – Expert (Can use at superior level of skill and teach to others)

Table 6 shows the gains in knowledge or skills after taking the course. The largest increase (120%) was centered on learning about EDM (Electrical Discharge Machining). This indicates that the Externship training reached its goal of informing high school educators about machining topics. The knowledge of advanced manufacturing careers increased 78% which indicates these faculty can better inform their students on potential careers in their field.

Comparison of level and knowledge of skills before and after Externship (weighted average)			
	Before Class	After Class	Percent Change
CNC Mills	1.28	2.50	95%
CNC Lathes	1.28	2.31	80%
3-D printers/Rapid prototyping	1.88	2.75	46%
Robotics/Animation	1.61	2.56	59%
EDM (Electrical Discharge Machining)	1.11	2.44	120%
Advanced manufacturing careers	1.72	3.06	78%
The advanced manufacturing environment at companies	1.61	3.19	98%

Table 6: Participant self-rating of their knowledge and skills pre-and-post Externship training. n=18 (Pre), n=16 (Post)

(For details on the Externship program, see Evaluation Question One in this report)

Symposium

In the May of 2021, a Symposium was conducted after being delayed two years because of COVID-19 preventing the implementation of in-person events. The purpose of this symposium was to determine the impact of exposure of advanced manufacturing on high school educators to arm them with knowledge when they discuss advanced manufacturing as a potential education and career path. Similar to the Externship Camp, educators were asked to rate how their knowledge changed before and after attending the symposium.

The survey used a five-point Likert scale. Ratings were assigned a numerical value from 1 to 5:

1 – No Knowledgeable
2 – Not Very Knowledgeable
3 – Somewhat Knowledgeable;
4 – Very Knowledgeable;
5 – Extremely Knowledgeable

Table 7 shows the gains in knowledge or skills after taking the course. The largest increase (92%) focused on how to program a mini-CNC mill using Autodesk Fusion 369. The low score of 1.71 taken before the symposium indicates very little knowledge on how to accomplish this task, and after the event, the rating of 3.29 indicated the educators became somewhat knowledgeable. The other two topics which centered on differences in two fields and types of careers changed from 3.14 (somewhat knowledgeable) to 4.0 and 4.14 (very knowledgeable), indicating that educators can speak with confidence to their students about this field and types of careers available.

Comparison of level of knowledge before and after Symposium (weighted average)			
	Before Class	After Class	Percent Change
Types of careers available in advanced manufacturing	3.14	4.0	27%
Differences between manufacturing engineering and mechanical engineering	3.14	4.14	32%
How to program a mini-CNC mill using Autodesk Fusion 369	1.71	3.29	92%

Table 7: Participant self-rating of their knowledge pre-and-post Symposium training. n=7

Similarly, participants were asked their level of interest in these topics and did this level change because of the event. (See Table 8.)

The survey used a five-point Likert scale. Ratings were assigned a numerical value from 1 to 5:

1 – No Interest 3 – Somewhat Interested 5 – Extremely Interested

2 – Not Very Interested 4 – Very Interested

Comparison of level interest before and after Symposium (weighted average)			
	Before Class	After Class	Percent Change
Types of careers available in advanced manufacturing	3.86	4.47	18%
Differences between manufacturing engineering and mechanical engineering	3.43	4.43	29%
How to program a mini-CNC mill using Autodesk Fusion 369	3.86	4.57	18%

Table 8: Participant self-rating of their interest pre-and-post Symposium training. n=7

The survey revealed that participants were definitely interested in these topics prior to the symposium, so a smaller change than their advanced knowledge is not surprising. However, their interest after the event increased to between very interested and extremely interested. This could indicate that their interest increased even more after learning about the topics, so further events could be offered in these areas. These educators are the front line in getting high school students interested in advanced manufacturing, and the grant team are commended for implementing an event where participants not only gained knowledge, but their interest in these topics.

Some comments from participants underscored this impact:

> *"There are many career opportunities in the Pottstown Area for CNC machinists. I want to be able to speak effectively about the topic to gain interest from my students."*
>
> *"It provided an opportunity to introduce CNC technology to my students."*
>
> *"Great resources and job opportunities await students in manufacturing engineering, especially at Penn College of Tech!"*

New Curriculum

Development for the majority of curriculum was completed in year one of the grant, and further creation and updates occurred in year two. Revisions to all machining programs occurred in the spring of 2021 for fall 2021 implementation.

The year 3 improvements include:

- Eliminating redundancies in course outcomes,
- Adding additional CNC content to the certificate program,
- Changing course sequences to make CNC learning more effective,
- Creating a new multi -axis course CIM 228 (CIM 206 and CIM 221 were rolled into CIM 228). This allowed for new content on multi-axis machining and created the equivalent of three courses in one.

The CNC Machinist Certificate was implemented in the Fall Semester of 2020. This one-year program includes the following courses:

CIM102 – Introduction to CAD/CAM

MTT128 – Mill Applications

MTT 129 – Lathe Applications

CIM104 – CNC Machining and Programming I

CIM124 – CNC Machining and Programming II

MTT213 -Machine Tool Applications

MTT131 – Quality Control with GD&T

The CIM102 course was created to launch the first semester of all four manufacturing programs: the CNC Machinist, the newest certificate; Automated Manufacturing Technology A.A.S.; Machine Tool Technology A.A.S.; and Manufacturing Engineering Technology B.S.

In addition to this new course, the program added and/or revised course outcomes in the basic machining courses, Metrology and GD&T course, and Fixture Design and Fabrication course MTT222 and revised the CIM 104 class to include information that can now be taught with machines purchased through grant funding.

Another new course was created, CIM 228 Advanced Multi-axis CNC Machining and Programming course, which will be included in the Automated Manufacturing AAS degree, as well as in the Manufacturing Engineering Technology B.S. degree.

The new curricula and revisions to existing courses align with new equipment and technology provided by the grant and an alumnus donation. In year three, the college approved changes to the associate degrees and bachelor's degree to align the certificate courses allowing transfer of the majority of these courses into advanced degrees. CNC certificate constitutes year one of the AAS, allowing a student to earn three degrees on their way to the BS. (CNC – year one, AAS, year 2, BS, year 4.) This is an outstanding result, and a highlight of the impact of this grant.

Additionally, the Apprenticeship Technology degree was approved for implementation in the fall of 2022. Credits earned in this degree can apply toward an ASS degree.

In tracking the changes to curriculum and degrees, the project kept meticulous documentation on deleted courses, new courses, revised courses and moved courses for each degree, along with a

mapping of skills/course outcomes in each course. This information will be very helpful in updating future program changes.

As noted in the section of this report for Evaluation Question One, new equipment purchased through the grant and equipment purchased through a large donation from an alumnus and foundation allowed the curriculum to be updated to the latest technologies in the industry, preparing students for the globally competitive manufacturing workforce.

Consistent with the goal of continuous improvement, a 5-question survey was developed and sent to the faculty for their input on the curriculum in the program. Only three faculty responded to the survey, so the responses are more anecdotal and qualitative. The only question with a "Yes" or "No" response asked faculty if they believed students are more prepared for CNC operations, set-up and programming in later classes (CIM124, MTT222 and MTT213) due to its inclusion in MTT128 and MTT129.

Two of the three faculty responded with "Yes" and one with "Not Sure." The following comments explain their responses:

> *"With the revisions to the CNC sequence, the student preparedness and knowledge of the CNC programming, setup and operation seems to have improved. Students seem more comfortable and confident with learning various machine controls and programming format, along with conversational type CNC machining."*
>
> "Yes" response
>
> *"I believe it is a bit early yet to evaluate this. Faculty are still being trained on new equipment and getting curriculum adjusted to accommodate and satisfy new and revised required student outcomes. We are hoping student CNC preparedness becomes reality but, true assessment may be a semester or two away."*
>
> "Not Sure" response

The college could consider repeating this survey subsequent years to determine of the data set is larger and if more students have advanced through the program.

This year's survey, however, provided specific feedback on the advantages of two new courses (CIM102 and CIM 104), along with disadvantages and how curriculum could be re-aligned.

Advantages:

- Better understanding of CNC principles
- Stronger knowledge base and comprehension of CNC automation setup, programming and operation techniques earlier in the program
- Better understanding of CAD and more engagement

Disadvantages:

- A lot of information for students to absorb in the first semester
- Learning manual milling and turning techniques at the same time as CNC basics slowed down productivity
- Students lack basic machining skill sets, blueprint reading and quality control techniques, because they are simultaneously learning them in two other classes

Curriculum Realignment:

- The last two years of the four-year program need updating
- Possibly go back to 8-week block format for some courses and move to three day/week schedule for other courses
- Review timing of skill sets in revised first semester classes to avoid redundancies
- Possibly combine CIM102 and CIM 104 into one course

Impact on Classroom Instruction

High School Courses
High school teachers (and counselors) who took Externship training in the Summer of 2021 reported being better prepared to teach manufacturing concepts to their students. Participants were almost unanimous in saying they were highly likely to implement ideas and concepts learned in their Externship. They also believe the participation in the externship will be a strong impact on students. In estimating how many students these educators anticipate will be impacted by these learnings, the seventeen participants estimated 3,260 students. This is a significant impact from one event, and the college could consider doing a longitudinal survey a year or two after this camp to determine how many students were impacted and how they were impacted. The educators could also be solicited for feedback on what they've learned by delivering this content to the students and what they might recommend as change for a future event.

Impact on Students

International Study Trip to Germany
As noted earlier in this report under Question One, secured supplemental funding to provide an educational study trip to Germany. On the 16-day trip, 7 students and 8 faculty chaperones and four business representatives received training at the Eckert International Vocational School.

After the trip, students and educators were asked for feedback on their experiences. (Faculty feedback as reported in Evaluation Question One in this report.) The photo, Figure 5, shows the students and their hosts. This was pulled from an article about the international study on the college's website.

Figure 5. PCT Students and their German manufacturing hosts.

All 7 students responded to the survey, which asked for written comments on:

- Top 3-5 exciting/new things learned
- Advantages of German system over US system
- Advantages of US system over German System
- Have career goals changed and how

In addition to learning about German culture and how different companies operate, students also learned that many German attitudes were like their own and related the experience of being out of the country for the first time. A sample of **new things they learned** include:

- Learned new manufacturing operations
- How to operate a Kuka robot
- Everything is automated
- Learned about dual vocational training
- Hands-on experiences with German CAD/CAM software
- Customization on Just-in-Time production line
- Learned new software tools

Students picked up a lot of information on how the German system of preparing students for jobs in adulthood begins at a much younger age than in the U.S. Some of the **advantages of the German system compared to the U.S. system** include:

- German Dual System provides pay while working and going to school
- Education is specialized for specific jobs
- Students motivated to pursue education leading to work
- German education and training is inexpensive
- Education and training for career starts at young age
- Many jobs tied to automation

Students were also able to compare their experiences in the U.S. educational system compared to the German system, with the recurring theme in their answers of personal choice by students. Some of the **advantages they found in the U.S. system compared to the German system** include:

- Summers off to relax rather than year-round school
- More broadened education and more flexibility of where the graduate works
- U.S. schools can create unique curriculum with different educational tracks
- The U.S. system allows flexibility across a career path, as opposed to training towards a specific job in the German model.
- Upon entering college, students are allowed to choose any major without government intervention

This international trip was eye-opening for the students, and they learned a variety of things about the differences in two countries' education and career paths. To determine if the trip had an impact on their educational goals, students asked if their **professional and/or educational goals changed**. Some comments noted that students were already in the advanced machining path.

- Yes, learned about Industry 4.0 and how impactful it can be. Will bring these lessons back with me.
- No, reinforced the idea of pushing for advancement and continuous improvement.

- Not exactly changed, showed me opportunities in Germany companies and future career goals.
- No, but have become more confident in my work and to never stop learning.
- Yes, now understand various differences in real-world situations. I enjoyed networking and learning from professionals in a different country.

Based upon feedback from the students, and from their educational advisors on the trip, this was a very valuable experience. The college could take the opportunity for these students to speak to advanced manufacturing classes to provide insight on what they learned and how they are going to apply this to their education and career. The college and grant team are commended for pursuing supplemental funds to allow this trip to happen and to ensure the logistics worked well at the German site. As students get hired into U.S. industry, they can also apply what they've learned to their new career.

CONCLUSIONS

Conclusions

The major finding from this evaluation report is that the 19MAC Project met or exceeded its goals. The team built the infrastructure of people, curriculum and equipment needed to complete the project's goals and timelines and had the resources in place to meet its objectives over the course of the grant.

In year three, the grant team under the leadership of Co-PI Bradley Webb achieved its goals for the year, with minor delays due to the pandemic. Highlights include:

- A trip to Germany for students, teachers and business representatives to observe precision machining in the German education system,
- The first graduates of the new CNC certificate program,
- The approval of the Apprenticeship Technology Degree,
- Revisions to multiple machining programs and courses,
- Increased enrollment in the AAS and BS programs,
- A $1 million grant from the HAAS Foundation for additional multi-axis machining and renovation to the advanced manufacturing lab and,
- Conducting a Teacher Externship and Student Symposium,

The grant team is to be commended for gathering information provided by participants in the Externship training and sharing it in a repository via its website to be used by public school educators. Additionally, they are to be commended for expanding this training to the aviation program and to middle school and high school parents.

The grant is be congratulated for improving the advanced manufacturing machining program through faculty training, upgrades to courses and securing donations that allow for new equipment in the lab and upgrades to the lab.

The grant team is also commended for conducting a successful international study trip for students, faculty and business representatives. The team and college pursued supplemental funding for this trip

which could have a lasting impact on the students who participated. These students can share their experiences with other students, which could inspire them to pursue this field as a career.

Co-PI Webb encapsulated the accomplishments of this grant: “I think this grant created a snowball of other wins for advanced manufacturing. We’ve received $2M in donations, renovated one shop, are planning a major renovation to another, and enrollment is slowly ticking up. I believe the grant got the ball rolling on these initiatives. I’m also extremely pleased with the numbers of students, parents, and teachers we were able to connect with and dispel myths surrounding careers in advanced manufacturing.”

Congratulations to Co-PI Webb and his team.

Appendix One: Approach to Evaluation

Theoretical Foundation

The evaluation is primarily based on adaption of the Context-Input-Process-Product evaluation model developed by the Evaluation Center at Western Michigan University, under the direction of Arlen Gullickson, PhD and Daniel Stufflebeam PhD[1]. The year's activities were evaluated following Gullickson's four essential elements:

1. The degree to which the project is achieving its goals.
2. The level of impact, and the degree to which the project is reaching intended individuals or groups.
3. The effectiveness of the products and services delivered to constituents.
4. Ways in which the project can be significantly improved.

The investigative approaches recommended by the Evaluation Project at Western Michigan University were utilized to produce a theoretically based, complete and comprehensive review of the project:

- Objective Orientation: How closely the products and services meet the stated goals and objectives as stated in the grant proposal.
- Teaching/Learning Process Orientation: Based on the perspective of teachers, how the project activities are assisting or facilitating teaching and learning.
- Customer Orientation: From the perspective of students, how the project activities are improving learning, comprehension and retention.
- Faculty and Institutional Support: The degree to which the project efforts are integrated and accepted, and the positive changes resulting from the efforts.
- Business and Industry Support: The level of acceptance and support for the project efforts by business and industry, especially those which hire graduates and utilize the technician workforce.
- Management: The degree to which processes are in place or under development that leverage the effort with the goal of building on the project activities, products and services after the funding period comes to an end.

Each item in the evaluation plan was considered from one or more of the approaches listed above. The following methods were used to develop the data necessary to cover the topics in the evaluation plan:

- Interviews with Principal Investigator, Co-Principal Investigators, project staff, partners and faculty.
- Determination of impacts and influences on technician level education.
- Analysis of documents.
- Analysis of applicable survey and other data gathered to date.

Project data-gathering activities and subsequent data analysis were guided by standards developed by the Joint committee on Educational Standards and Evaluation. All active and passive data gathering activities involving human subjects were approved by the appropriate institutions' IRB (Institutional Review Board).

The evaluation covers findings and recommendations, discussions with PI and staff combined with findings of the data gathered through surveys, interviews and data analysis.

[1] [1]Stufflebeam, D. L. (2003). The CIPP model for evaluation. In D. L. Stufflebeam, & T. Kellaghan, (Eds.), *The international handbook of educational evaluation* (Chapter 2). Boston: Kluwer Academic Publishers.