Implementing the Mechanisms to Lessen the Talent Gap in Advanced Manufacturing

An NSF/ATE Project DUE 1902379

EVALUATION REPORT

Year 2: February 1, 2020 to January 31, 2021

Presented to:

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Acknowledgments

Co-Principal Investigator Bradley Webb was instrumental in implementing the evaluation for year two 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 second year of operation.

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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
FLATE	Florida Advanced Technology Education Center
GD&T	Geometric Dimensioning and Tolerancing
MET	Manufacturing Engineering Technology
NSF	National Science Foundation
PCT	Pennsylvania College of Technology
PI	Principal Investigator
RCNGM	Regional Center for Next Generation Manufacturing
RSO	Required Student Outcomes
SLS	Selective Laser Sintering
STEM	Science, Technology, Engineering and Mathematics
TAG	The Allison Group

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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. Pennsylvania College of Technology (Penn College) 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 will realign 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 will support the increased placement of highly qualified graduates into regional industry positions.

In year two, the grant team under the leadership of Co-PI Bradley Webb has been on track and/or achieved its goals for the year, with minor delays due to the pandemic. Highlights include:

- Purchasing the state-of-the-art equipment,
- Creating and implementing a professional development course,
- Storing course materials in the cloud for long-term access,
- Developing a relationship with Sinterit to use Sinterit Lisa for study and reuse,
- Creating two new technical courses,
- Modifying four technical courses,
- Changing the course progression on the education path to improve student understanding of concepts in a logical way, and
- Conducting a Teacher Externship week-long training and information seminar.

Despite challenges from the COVID-19 pandemic, the team was able to find alternative solutions to delayed shipping of equipment and to consider conducting virtual symposiums to replace an in-person student symposium which was cancelled.

An alumnus of the Pennsylvania College of Technology donated the largest gift in the school's history to the program, supplementing the four new machines purchased through grant funds with an additional 25 machines. The boost in lab equipment will allow for the acceleration of curricular revisions.

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 SLS technology available for two-year AAS students.

Continuing to collaborate with the evaluator on strategies to assess the program and ensure the full participation of stakeholders in the assessment process should remain a priority for year three.

All indications are that this grant will meet and exceed its goals for the grant.

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. 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 will realign Penn College's manufacturing curriculum to embed more technologically sophisticated skills, create a new CNC certificate program and increase enrollment in Penn College's two-year AAS degrees in Machine Tool Technology and Automated Manufacturing. The grant will support the increased placement of highly qualified graduates into regional industry positions.

This report covers year two of the 19MAC project grant, for the period February1, 2020 to January 31, 2021. The evaluator and Co-PI Webb met monthly. 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 two. One of the goals was to produce 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 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
Indicator	**Data Sources & Methods**	**Analysis**
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

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 two, the external evaluator and Co-PI met in accordance with an established regular meeting schedule to update the evaluator on the project activities and establish a detailed data gathering plan and reporting schedule.

Additionally, the external evaluator, in collaboration with Co-PI Webb, developed a survey to obtain feedback on classroom teaching of the new curriculum and the prior existing curriculum. The survey was conducted in November-December 2020, and three of the ten faculty involved completed it. This compares with four of ten last year. All respondents completed it for multiple courses, adding up to ten total sections reviewed by faculty. 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 commendable.

In addition, the external evaluator developed pre-and-post surveys for the Externship participants. Thirteen of the fourteen participants (92.9%) completed the post survey, an excellent response rate.

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 second 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 anticipates 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.

Plans are for the new machine to be used in a course that the two trained faculty will be teaching 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 Jigs and Fixtures class.

Activities

The activities in Table 2 below reflect the status of tasks at the completion of the second 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		Done1
Prepare proposal for revised AAS degree programs		X		On track
Submit proposal and obtain approval		X		On track
Implement new AAS degrees		X		On track
Research awarding credit for apprenticeship			X	On track
Implement awarding credit for apprenticeship			X	On track
Select student project for symposium	X	X*	X	On track
Outreach to high schools for student participants in symposium day	X	X*	X	On track
Implement symposium	X	X*		On track
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	Modified/On track
Review lesson plans/instruction in the high schools		X	X	On track
Disseminate lesson plans		X	X	On track

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. A potential solution is to hold virtual symposiums and/or the manufacturing of products to distribute to participating schools for assembly, design review and operation.

The program activities for year two were met or are on track for completion with the exception of two events which were cancelled due to the COVID-19 pandemic. The on-campus student symposium, (see note above), was cancelled along with international travel to Germany to study and learn about methods of manufacturing and educational training. This latter opportunity was developed through a supplemental proposal to fund educational study in Germany, a world leader in CNC technology, and the home of the German Vocational Training System. The grant team submitted an appeal to retain funding for future international training if travel restrictions are lifted.

Two new courses were developed and four were modified in year two, and details on these activities are addressed in Question 3.

Externship Program

The project team and college worked collaboratively to host a summer Externship program for 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. In addition, this activity should help prepare high school instructors to talk about careers in manufacturing with more detail and a better understanding of today's advanced manufacturing sector. The inclusion of high school guidance counselors in the Externship provides another point of contact for high school students to learn about these careers.

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 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).

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

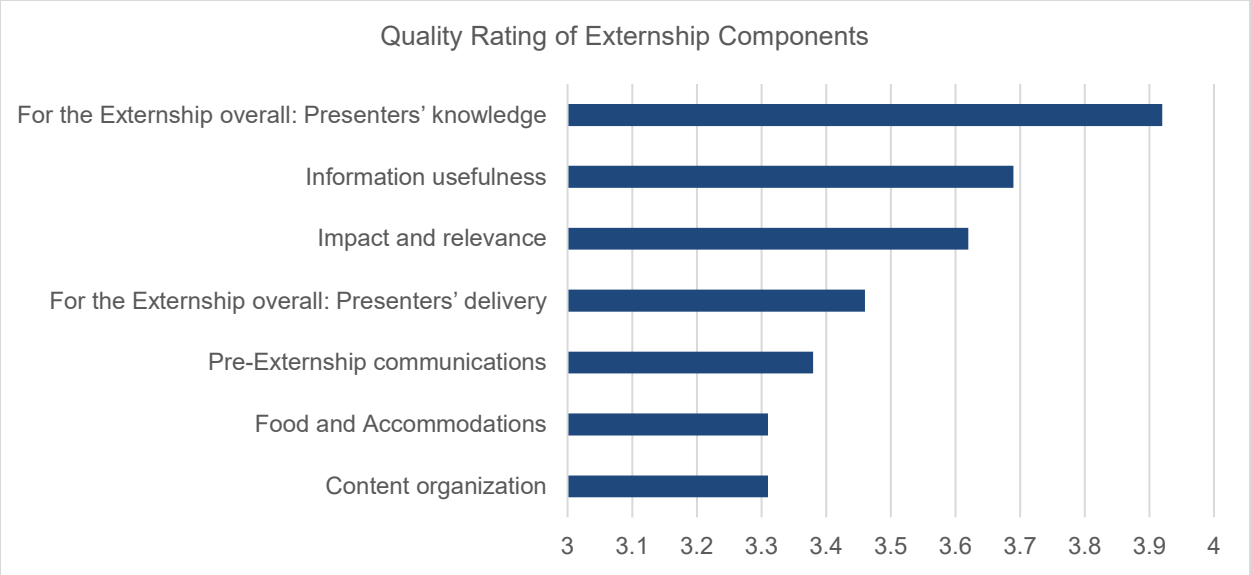

Figure 1: Quality of Externship Components (weighted average), n=13

As can be seen in Figure 1, the content of event, including the presenters' knowledge, usefulness of the knowledge and its impact and relevance received high marks. Participants offered suggestions for future offerings and compliments to the organizers of the event.

> *"This has been a great experience! The best professional development I've attended."*
>
> *Externship Participant*
>
> *"I was very impressed with Josh and his expertise, a great testament to your courses, programs, and the education being provided to students at Penn College."*
>
> *Externship Participant*

The grant team can use some of the feedback from participants to reinforce effective parts of the program and enhance others.

When asked about presentations and activities that were valuable, participants were particularly pleased with tours, hands-on activities, robotics demonstrations and information on engaging students, including career options. Considering that participants included teachers and counselors, some of the participants had no knowledge of this technology but were able to learn enough about advanced manufacturing to share with students, who would also know very little about this industry.

> *"I really liked that all ability levels were taken into consideration and your staff were so patient and terrific. I felt comfortable the entire time, and probably had the least amount of "natural ability" in the class. That is so important, as students come from all different learning abilities as well."*
>
> - *Externship Participant*

Some participants suggested cutting the length of some of the presentations or breaking them up into shorter segments. One suggested providing a list of YouTube videos as pre-Externship homework to set up a context for those who are not familiar with the field or its terminology. This seems to be a doable suggestion and might also be helpful to students who want to learn more.

Other specific suggestions included:

- Setting up a chat platform for participants
- Allow more time for hands-on experiences
- Streamline robot building and setup by getting more faculty involved
- Allow time for idea sharing, lesson planning and materials to deliver later to students and colleagues
- Offer a 3D printing project
- Consider having an instructor oversee an "assembly line" process to check the bot programming activity to help spot those having trouble and assist them

Many of these suggestions seem doable for subsequent Externship training and would also be good insight for faculty as they teach students, using these same ideas. It should be noted that these participants expressed gratitude for this opportunity and were looking forward to sharing the experience with their students.

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 of an alumnus donation. 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. This modernized facility will also help in recruiting new students. The donation from Mr. Ward also reinforces his confidence in the program to produce graduates with skills that can move into industry jobs. He said, "Throughout my career, I've always looked for a return on my investment, and when I see these kids here at Penn College, I just feel like I'm getting my money's worth."

Dissemination

During the second 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. Despite the cancellation of two activities – student symposium and international study abroad – the grant team was still 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 6 unique activities:

- K-12 teachers and counselors – 23
- Two-year faculty – 2
- Students – 23
- Industry- 9
- Conference attendees - 150

The grant gave two presentations at the October 2020 ATE PI Conference in Washington, D.C., held yearly for NSF ATE project and center recipients. Rick Hendricks and Dr. Brad Webb, the grant's PI and Co-PI, gave presentations to their peers and also participated in sessions and networked with other project recipients to learn strategies being deployed from various grant teams. Bridgerland Technical College (Utah) reached out to the 19MAC team for support in their ATE grant application.

Additionally, the grant has a website related to the project to disseminate new developments to the community. 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.

Since the pandemic has limited or eliminated face-to-face engagements, the grant team is encouraged to continue and pursue other virtual opportunities to reach students, faculty and community members. Perhaps they can seek guidance from the college's PR department on ways to utilize social media as another information tool. They might also consider posting a success story of either a student or faculty member receiving training as a link on the home page of the college's website.

Industry Collaboration

19MAC engaged with a variety of industries in year two 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; and advisory board session. PI Hendricks represented the grant program at a virtual meeting of the Jersey Shore Area School District Advisory Board meeting for Manufacturing, attended by 23 participants from the community.

The grant team might consider reconvening a virtual meeting of the manufacturing advisory group from the first year to update them on new developments in the program and to solicit feedback.

Supplemental Proposal

As mentioned above, the project identified an unexpected opportunity and submitted a supplemental proposal to fund an educational study visit to Germany. On the proposed 16-day trip, 10 students and 2 faculty chaperones would receive training at the Eckert International Vocational School, a leader in German Vocational Training, and meet with numerous companies that are on the cutting edge of CNC and automation technology, such as Voith, Siemens, and BMW. The trip would allow the faculty to experience the dual system in action and give students exposure to a tailored German Industrial Training

designed specifically for the group. The faculty participants would also participate in a workshop on the dual vocational education system and have access to Eckert faculty and the program administrators for in depth discussions. Eckert agreed to manage and lead the training, provide educational materials, and arrange some company visits. Unfortunately, due to COVID-19 international travel was canceled, which included this study opportunity. The grant team submitted an appeal to retain funding for future international training when travel restrictions are lifted.

Although this trip has been canceled, the grant team could reach out to their German counterparts and determine if any virtual tours or information sharing could occur. The team is to be commended for securing this opportunity and appealing the in-person study for a later time.

Collaboration with Colleges and Other ATE Centers and Projects

As reported in the Dissemination section, Bridgerland Technical College (Utah) reached out to the 19MAC team for support in their ATE grant application. Because COVID-19 has limited the in-person visits to ATE centers and projects, perhaps the grant team would consider a joint faculty meeting with the 19MAC instructors at advanced manufacturing ATE Centers, such as Florida Advanced Technology Education Center (FLATE), Minnesota State Advanced Manufacturing Center of Excellence or Regional Center for Next Generation Manufacturing (RCNGM).

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. Since the enrollment data is only from one semester, more data will be needed to determine what trends, if any, can be seen in increasing the number of females and students of color. Table 4, below, shows the enrollment numbers for classes in the Fall Semester 2020 and the breakdown of female students and non-white students. Note: These non-white male students are also First Generation college attendees from their families.

Course	Total	Female	Non-White
MTT128	24	1	3
MTT129	25	1	2
CIM102 (new course)	25	1	2
CIM104	24	0	2

Table 3: Enrollment numbers for courses in Fall 2020

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 5 shows the breakdown of low-income students who enrolled in classes from fall semesters in 2018, 2019 and 2020. (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 did not increase in 2020. However, due to the COVID-19 pandemic, these 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. (One of the strategies of the grant is to provide opportunities to students from underrepresented demographics who would not normally enter this career field.)

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

Table 4: Low Income Student Enrollment comparing Fall Semesters 2018-2020

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 two years ago but was slightly down from last year. The grant team 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, and if any grant activities influenced their decisions. This information could be gathered from discussions with their teachers and counselors who attended the summer Externship, student recruitment events or information events such as college career fairs.

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

Table 5: First Generation Student Enrollment comparing Fall Semesters 2018-2020

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

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 starting the Externship, participants completed a brief survey to assess their level and knowledge of skills. Upon completion of the week, they were asked to assess these same skills. 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 3 shows the gains in knowledge or skills after taking the course. The largest increase (48%) was centered on learning about advanced manufacturing careers. This indicates that the Externship training reached its goal of informing high school educators about these careers so they can inform their students.

Comparison of level and knowledge of skills before and after Externship (weighted average)			
	Before Class	After Class	Percent Change
CNC Mills	2.0	2.46	23%
CNC Lathes	1.92	2.46	28%
3-D printers/Rapid prototyping	2.5	2.77	11%
Advanced manufacturing careers	2.5	3.69	48%
The advanced manufacturing environment at companies	2.67	3.46	30%

Table 6: Participant self-rating of their knowledge and skills pre-and-post Externship training. n=12

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.

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 MET (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. The college is on the cusp of approving 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. Approval for these changes should occur early in the third year of the grant, allowing implementation in the Fall Semester of 2021.

As noted in the section of this report for Evaluation Question 1, new equipment purchased through the grant and equipment purchased through a large donation from an alumnus 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 survey was developed and sent to the faculty for their input. Faculty were asked to rate the quality of the curriculum components, using a four-point Likert Scale. Ratings were assigned a numerical value from 1 to 4:

1 – Poor
2 – Fair
3 – Good
4 – Excellent

As shown in Figure 2 below, the components with the highest ratings, (3 and above) were Conversational CNC setup, programming and operation. The ones with the lowest scores, (below a 1), were Conversational lathe programming and Traditional and GD&T dimensioning concepts. The items rated between 1 and 2 would be considered as a low rating: CAD mechanical drawing design and creation, CAD basics, Conversational mill programming, Conversational lathe operation and Conversational lathe setup.

In delving deeper as to why some items were rated lower, comments included that conversational mills and lathes don't have programming; lathes were not used in one class but used mills instead, and those who taught lathes classes rated mill components lower and vice versa. Perhaps the CAD rating would also reflect that only the CIM102 instructor rated it higher; one instructor rated the CAD component as excellent. Perhaps this survey question needs to request that respondents only rate the components that were covered by the their class. In addition, the project might consider discussing the ratings from the survey at one of the faculty meetings in order to clarify faculty feedback.

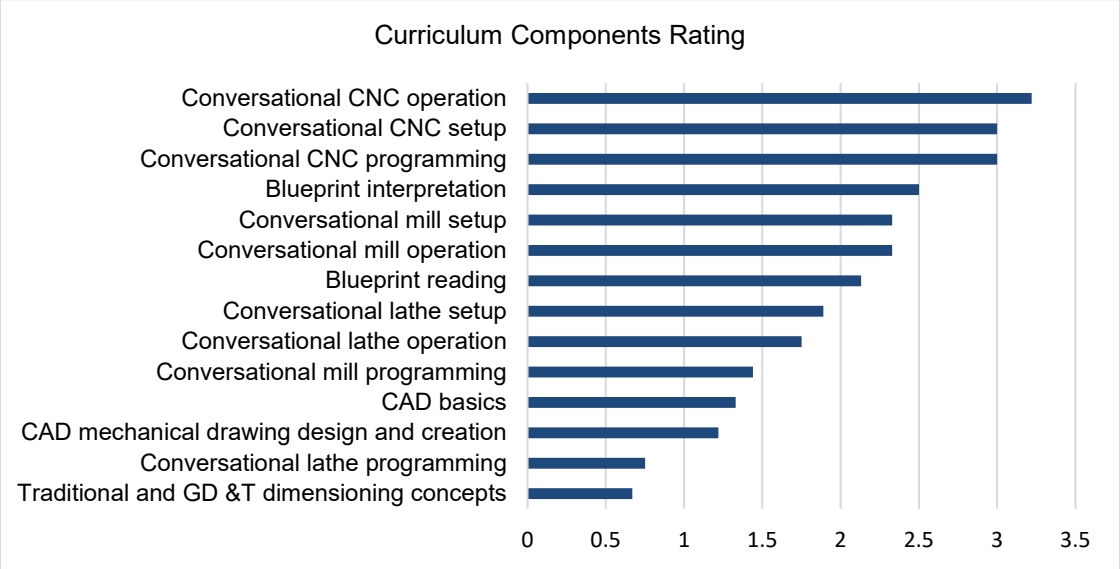

Figure 2: Quality of Curriculum Components (weighted average), n=9

Participants were asked for feedback on what could have helped them prior to teaching the curriculum and the curriculum itself, and many pointed to the learning curve for new curriculum and

gaining familiarity with the new machines in the lab. Other suggestions included:

- More structure for classroom and lab components for Proto Trac machines,
- An established book or course curriculum,
- Have students split between sections,
- Make time to work with individual students on the new equipment and on troubleshooting,
- Change textbooks and remove easier projects to allow more time for the complex ones.

Several faculty members commented that they would take lessons learned from teaching in prior semesters to help them improve their teaching in subsequent semesters. When this survey is implemented again after these new/updated courses and machines have been used in multiple semesters, the grant team will be better able to discern what would be an improvement that is impactful versus the result of ramping up to learning new content and lab equipment.

The college did score high marks from faculty in the level of support it provided to faculty in delivery new curriculum, with almost 80% of those responding saying they felt highly supported or supported.

Impact on Classroom Instruction

College Manufacturing Courses

The grant team also surveyed faculty on the impact curriculum and classroom methods had on students in the classroom. Of the 10 instructors surveyed, four taught the new and updated courses in the Fall of 2021.

The four instructors noted the following, that students:

- Were observed to have an average to high degree of mastery of the content,
- Responded well to the new course sequence,
- Became proficient at set-up, programming and operating the new Trac CNC,
- Were enthused to work on new equipment,
- Had a higher mastery of convent in MTT 128 versus MTT118 (the course that was updated to MTT128),
- Had an increase in mastery with the addition of the conversational CNC,
- Had a strong grasp of concepts of CAD and CAM.

These anecdotal responses provide insight into what components work well in curriculum, and in particular that students taking the MTT128 updated course exhibited a higher mastery of skills than students who completed the MTT118 course prior to its update.

High School Courses

High school teachers (and counselors) who took Externship training in the Summer of 2020 reported being better prepared to teach manufacturing concepts to their students. They reported:

- Gaining hands-on experience with manufacturing equipment (e.g. mill, lathe),
- Identifying ways to infuse manufacturing education in their home classrooms/individual assignments,
- Learning new hands-on activities,
- Gathering curriculum ideas,
- Identifying best practices.

Following the Externship, participants had the opportunity to report how they used what they learned. One example came from a high school teacher who shared his experience with 50 physics students. He

used materials from the sessions for a class presentation, video of his working robot and photos of the session. He reported that students were engaged in meaningful discussions although they were not able to participate in hands-on activities due to COVID-19 restrictions. The grant team is collecting information from participants on scenarios to be shared with others so they will be prepared to teach similar activities in their classrooms. The grant team is to be commended for gathering and sharing this information via a repository to be used by public school educators.

After these high school teachers have more opportunities to implement what they have learned, the grant team may consider gathering feedback on how the learnings from the Externship impacted students.

Impact on Students

As noted from the teacher survey results, students exhibited a higher mastery of content and became proficient in working with new lab equipment. The PI reports that students and faculty are now using more CNC equipment that primarily use conversational programming and machining techniques. These machines are commonly used in many types of manufacturing industry and add technology diversity to student portfolios. These types of experiences make the students attractive candidates when interviewing for jobs.

Additionally, students receive training on CNC equipment and programming, CADCAM and other automation techniques earlier in the curriculum and now receive more automation training in the certificate, associate and bachelor's programs. One new change is that students experience CNC in their first semester of the program, as opposed to the third semester.

The training of faculty in the Externship workshop should also produce results in subsequent semesters. In their survey, participants estimated over 2,800 students will be impacted by what they learned. They also reported:

- over 75% of the participants said they are extremely likely to implement ideas and concepts learned during the Externship
- 62% believe the Externship will have a high impact on their students;
- almost 70% said because of the Externship, students will have an increased understanding of manufacturing processes.

If only a fraction of the anticipated 2,800 students develop an interest strong enough to enter the program, this would be an impressive result of this training. As suggested earlier, perhaps the grant team could interview onboarding students into the program to determine what influenced their decision to enroll.

Faculty who taught the four manufacturing courses in the Fall of 2021 were surveyed regarding the impact of curriculum on students. All respondents said the curriculum was effective or extremely effective in improving student learning. "I saw a spark in the students like I have never seen before," noted one instructor.

Instructors also noted the impact of 21st Century Skills (communication, teamwork, meeting deadlines, problem-solving and critical thinking) on their students. While some observed these skills on display while working on projects, most expect the skills to improve over time as they progress through their degree or certificate credential. The grant team is to be commended for soliciting feedback not only on technical skills, but "soft" skills which are more difficult to teach, but very necessary when working on the job.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

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

In year two, the grant team under the leadership of Co-PI Bradley Webb has been on track and/or achieved its goals for the year, with minor delays due to the pandemic. Highlights include:

- Purchasing the state-of-the-art equipment,
- Creating and implementing a professional development course,
- Storing course materials in the cloud for long-term access,
- Developing a relationship with Sinterit to use Sinterit Lisa for study and reuse,
- Creating two new technical courses,
- Modifying four technical courses,
- Changing the course progression on the education path to improve student understanding of concepts in a logical way, and
- Conducting a Teacher Externship week-long training and information seminar.

The grant team is to be commended for gathering and sharing information provided by participants in the Externship training and sharing it in a repository to be used by public school educators. They are also to be commended for synergizing the usage of machines purchased through the grant with the additional equipment donated to the program to not only update the lab but also to support the enhancement of curriculum. The alumnus' donation, the largest in the college's history, also speaks to the confidence the business alumnus has in the program..

The 19MAC team is acknowledged for its flexibility, innovation, and focus, despite the COVID-19 restrictions. In the time covered by this reporting period, the project has accomplished the goals planned for year two and is on course for exceeding its goals and objectives planned for the grant overall.

Recommendations

Ideas to consider for year three are:

1. Consider identifying an individual or organization that can provide expertise related specifically to increasing the participation of underrepresented students in advanced manufacturing.
2. Review suggestions from participants in the Externship program and consider which ones might enforce what works well in the training and what could improve the session. The recommendation to provide a list of YouTube videos as pre-Externship homework would not only be helpful to high school teachers and counselors who are unfamiliar with advanced manufacturing but could be useful in recruiting new students.
3. Explore options for virtual engagements while the pandemic continues to impact in-person events. The grant team could seek guidance from the college's PR department on ways to utilize social media and an information tool, and they might consider posting a success story of either a student or faculty member receiving training as a link off the home page of the college's website.

4. Consider a joint faculty meeting between advanced manufacturing faculty at the college with peers from institutions served by other advanced manufacturing ATE Centers (such as Florida Advanced Technology Education Center, Minnesota State Advanced Manufacturing Center of Excellence or Regional Center for Next Generation Manufacturing.) Sharing lessons learned and new ideas for implementing new curriculum on new equipment could be mutually beneficial.
5. Explore the possibility of participating in a virtual tour or information sharing with the German center which was to host the international study. This would not replace the trip but could supplement it when travel restrictions are lifted and might produce ideas of what to explore when visiting the center in person.
6. Consider surveying first-year students in the program to determine what key factors led them to choose this discipline. The team could gain insights on what is most effective in recruiting new students, especially those from underserved populations. The team could also consider bringing in an employee from a diverse background as guest speaker (even virtually) to either recruiting events or to classes to serve as role models encouraging and inspiring students to pursue this profession.
7. Continue the excellent work with the evaluator to expand and develop data gathering methods and instruments to improve participant feedback to better inform outcomes.

APPENDIX 1

APPROACH TO EVALUATION

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.