



NORMANDALE
COMMUNITY COLLEGE

FINAL EVALUATION REPORT
DISTANCE EDUCATION AND
LEARNING IN VACUUM
TECHNOLOGY FOR EMPLOYER
READINESS (DELIVER) PROJECT

Normandale Community College – NSF ATE Award
#1700624



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Executive Summary

Vacuum technology is an area of study vital to nanotechnology, semiconductor fabrication, and other advanced manufacturing processes. To support these important industries, Normandale Community College (NCC) offers three (3) different credentials in Vacuum Technology:

- 1) Vacuum Technology Certificate – 9 credits consisting of VACT 1292, 2293 and 2297
- 2) Vacuum Maintenance Technician Certificate – 28-29 credits
- 3) Vacuum Technology AAS Degree – 60 credits

Project DELIVER (NSF ATE grant #1700624) proposed a combination of activities in the areas of program development and improvement, curriculum and educational materials development, and professional development for educators. The primary audiences impacted by the project were students seeking credentials in vacuum technology at Normandale, as well as other colleges and universities in Minnesota and Wisconsin and beyond. It also targeted faculty or potential faculty in vacuum technology from around the country.

Project DELIVER had three major objectives:

- Expand pathways for students into vacuum technology through development of asynchronous online learning courses in foundations of vacuum technology and preparatory math and vacuum science.
- Meet the education and credential needs of students and businesses by developing and testing a “focused track” credential that provides businesses with rapid access to skilled, knowledgeable technicians and that can be delivered to distance learners.
- Develop and share best practices to increase access to instructors with industry experience who are available to teach in vacuum technology programs.

The outcomes of successfully implementing the project activities include:

- Developing and validating a “focused track” credential to quickly move individuals along an educational pathway and into the workforce.
- Increasing access to vacuum technology education for a broad range of groups including students of color, women, and veterans.
- Providing a rapid path for students to attain a vacuum technology credential and obtain employment and skill development.

The desired NSF impacts addressed by this project include:

- Improved STEM education and educator development
- Development of a diverse, globally competitive STEM workforce
- Increased partnerships between academia, industry, and others
- Enhanced infrastructure for research and education

While a more detailed list of findings is included in the summary section of this report, Project DELIVER resulted in Normandale’s Vacuum Technology project team gaining extensive experience and significant lessons learned about successful practices for delivering technical learning through distance technologies, recruiting new instructors into technology programs, and supporting incumbent workers with education and training.

In addition, the industry workshops conducted as part of this project provided valuable insight into the current state of vacuum technology education in the U.S. while providing validation of and opportunities for continuous improvement to Normandale’s curriculum.

A summary of the key findings from the project are provided in the table below.

Summary of Key Findings
Enrollments, geographic reach of the program and number of organizations served are all trending upwards as a result of this project.
The program saw significant improvements in both quality and quantity of physical resources and infrastructure.
The program saw positive collaboration and impact on multidisciplinary initiatives, specifically with the engineering technology program and the physical sciences.
The primary motivation for students to take a vacuum technology course is the desire for career advancement.
The Foundations in Vacuum Science course was found to be very effective in preparing students for further courses in vacuum technology.
The quality of technical content in a program and the quality of the instructor are more important factors than the delivery method for student outcomes.
There is a steep learning curve attached to the implementation of VET systems into the courses and curriculum but they still had a positive impact on providing quality hands-on experiences to students.
Existing science and engineering faculty provided a better source for new instructors than industry.
Successful practices in recruitment of new instructors include: <ul style="list-style-type: none"> • Relationship-driven recruitment highlights the importance of program leadership and the trust and personal investment in the new instructors success. • Auditing/observing the class ahead of teaching was a key contributor to success. • Embracing problem solving and troubleshooting skills are key. • The project developed excellent resources shared with new instructors. • Collaborative teaching with new instructors was a positive experience.
Normandale’s vacuum technology program meets or exceeds the expectations of both industry and students.
The Undergraduate Research Experience (URE) supplement provided several positive impacts: <ul style="list-style-type: none"> • Enhanced student learning for vacuum technology students • Real world application of technical content • Enhanced faculty professional development • Improvement of Normandale’s vacuum technology curriculum and program by providing “hands-on” opportunities to distance learning students

Project Strategies and Activities

The specific activities and tactics for each primary objective of this project are outlined below.

- Expand pathways for students into vacuum technology
 - Develop and offer a Foundations in Vacuum Science course (VACT 1010) to address preparatory math and science topics related to vacuum science

- Develop and offer vacuum technology courses through synchronous and asynchronous online delivery formats
- Develop and deploy vacuum equipment trainers (VET)
- Develop and deploy automated VET for remote operation by students
- Pilot a part time student support liaison position
- Offer an undergraduate research experience (URE) supplement
- Develop a focused track credential in vacuum technology
 - Offer and validate a Vacuum Technology Certificate
 - Align curriculum across all courses in the certificate program
 - Conduct an industry workshop series to validate curriculum and assess industry needs
- Increase access to new instructors
 - Compare and evaluate the advantages and disadvantages of recruiting new faculty
 - From science faculty at NCC
 - From industry
 - Assess and improve the onboarding process for new instructors

Evaluation Framework

Logic Models

Logic models serve as a conceptual framework for connecting specific activities to desired broader impacts (see Figure 1). This conceptual logic model can be used to make sure there is a mutual understanding about the program's structure, connections and expected outcomes. The model is used to connect project activities to

- Formative outcomes – a measure of the program's implementation. Typically these are things that can be directly observed or counted.
- Summative outcomes – a measure of the program's impact. These outcomes can be categorized as either:
 - Changes in knowledge, skills or attitudes
 - Changes in behavior or policies
 - Changes in socioeconomic conditions
- Data sources – sources for measuring or evidence for the desired outcomes.
- Broader impacts - refers to the potential for a project or program to benefit society or advance desired societal outcomes.

In the case of NCC's NSF ATE DELIVER project, this means connecting the major activities of the project to the broader impacts of developing and validating a "focused track" credential to quickly move individuals along an educational pathway and into the workforce, increasing access to vacuum technology education for a broad range of groups, and providing a rapid path for students to attain a vacuum technology credential and obtain employment and skill development.

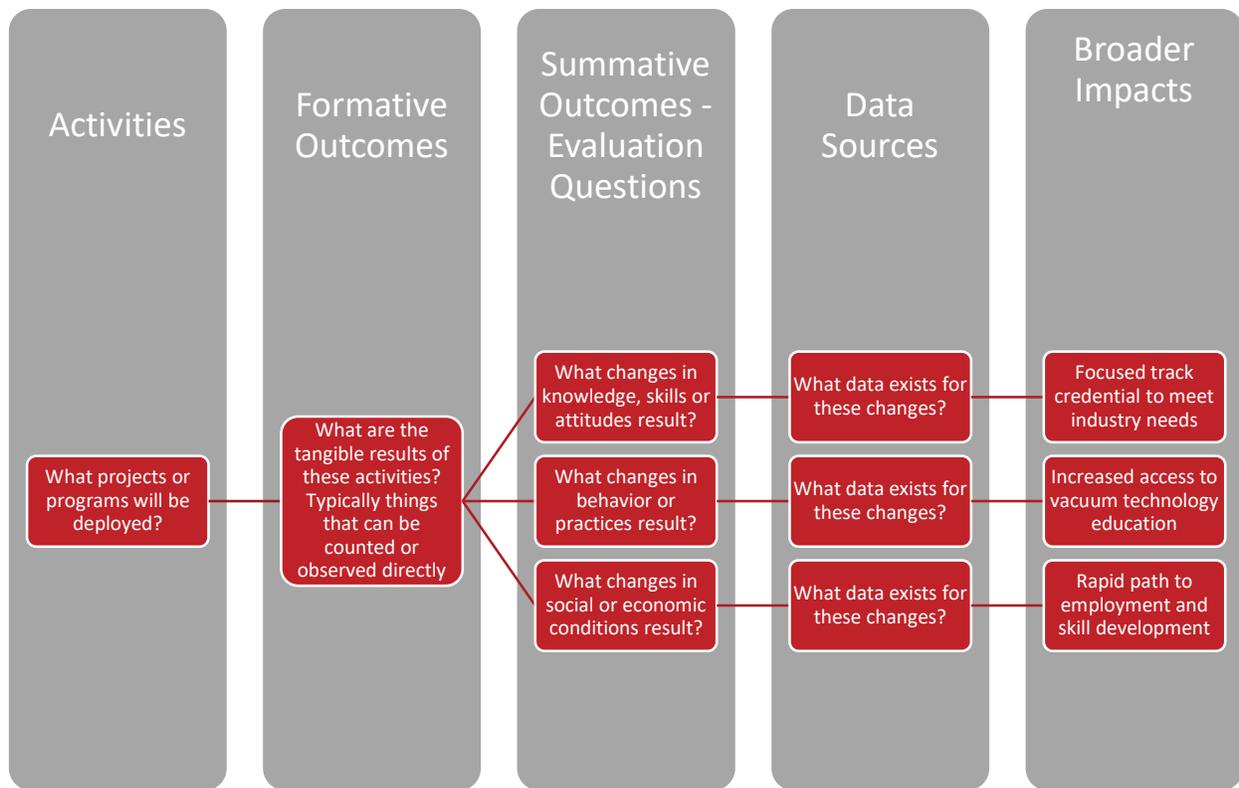


Figure 1 -Logic Model Framework for Evaluation

Evaluation Questions

The application of the project logic model yielded the following evaluation questions. In the remainder of this report, they will be referred to by the evaluation question number (EQ #) as listed.

- 1) What is the impact of adding multimedia content to the Normandale Vacuum Technology Certificate program in attracting target audiences to enter a course of study in vacuum technology?
 - a. **Revised:** What were the motivating factors that attracted audiences to enter a course of study in vacuum technology?
- 2) How effective is the Foundations in Vacuum Science course in preparing students for further courses in vacuum technology?
- 3) How effective is the blend of synchronous and asynchronous teaching and learning platforms [and hands-on learning] in delivering complex STEM content and in preparing students for work in advanced manufacturing?
- 4) Original: How effective is the revised vacuum trainer (VET) at providing adequate hands-on demonstration and lab experiences for complex deposition concepts and applications to improve learning and prepare students for work?
 - a. **Revised:** What did we learn about the barriers and successes of integrating hands-on demonstrations and lab experiences into the curriculum?
- 5) Is a focused track credential able to meet industry needs for skilled vacuum technicians?
- 6) What is the current state of vacuum technology instruction in the US?
- 7) Original: Is the workshop and mentoring model successful at attracting and preparing individuals from industry to become vacuum technology instructors?

- a. **Revised:** What did we learn about the barriers and success for attracting and preparing new instructors in vacuum technology?

Results and Findings

Formative Outcomes

The formative outcomes are discussed in detail in the annual reports submitted by the project PI. A brief summary of these outcomes is provided in Figures 2 through 8 below.

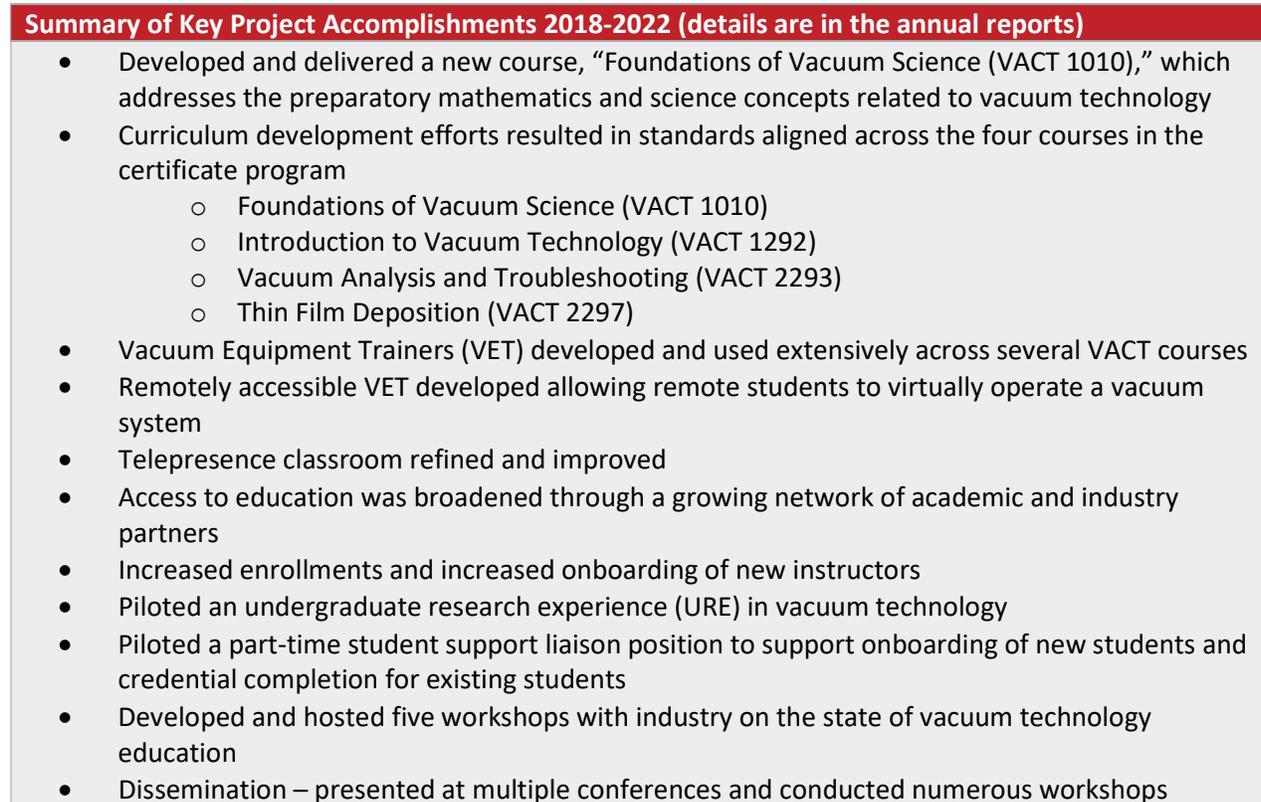


Figure 2 - Summary of Project Accomplishments

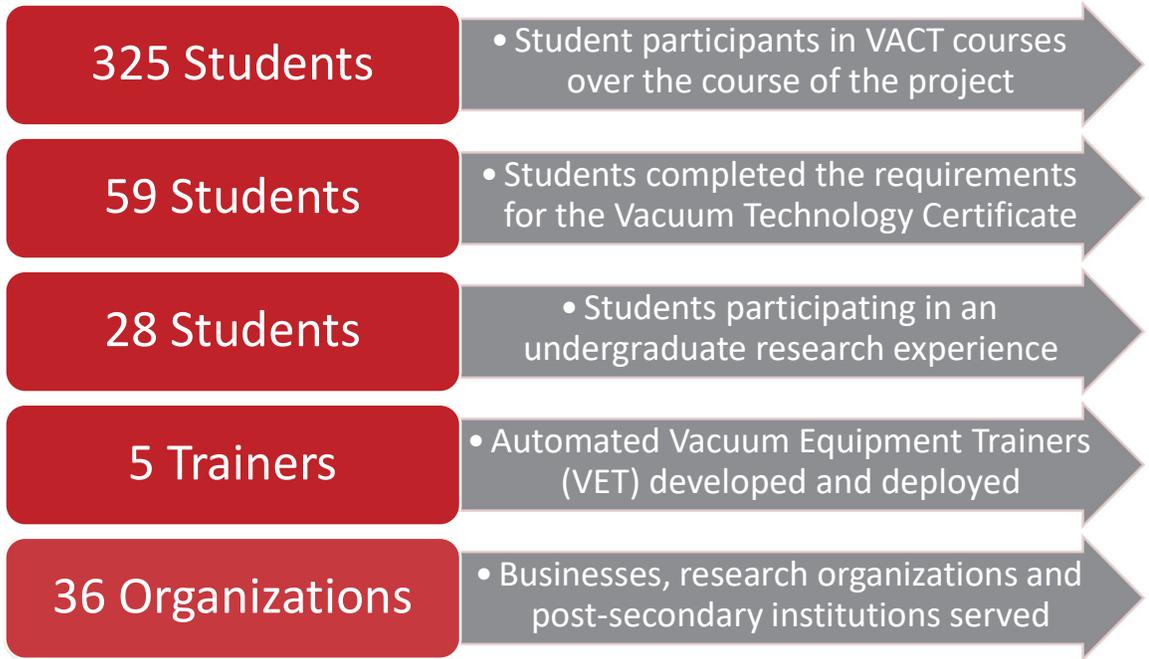


Figure 3 - Project DELIVER by the Numbers

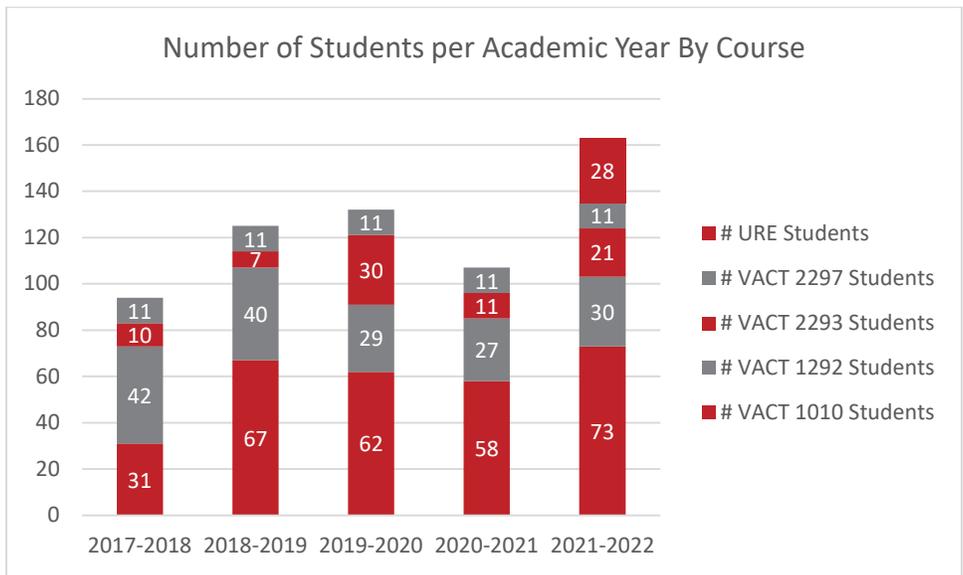


Figure 4 - Number of Participants by Academic Year by Course

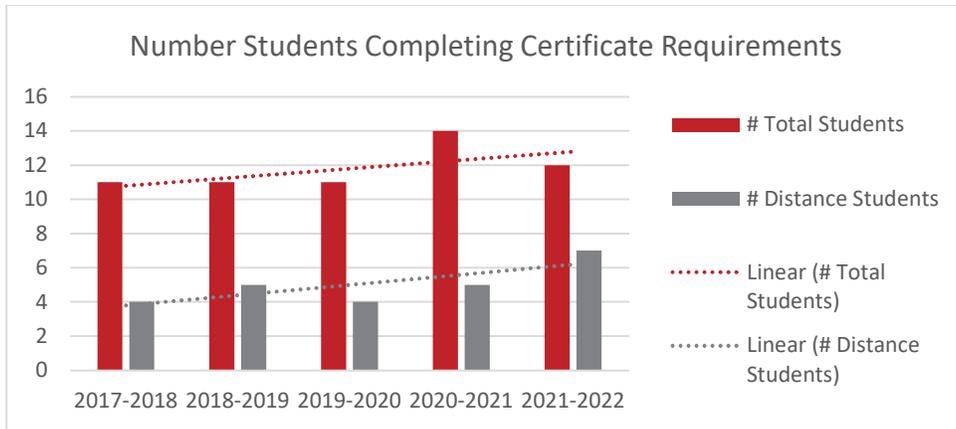


Figure 5 - Number of Students Completing Certificate Requirements

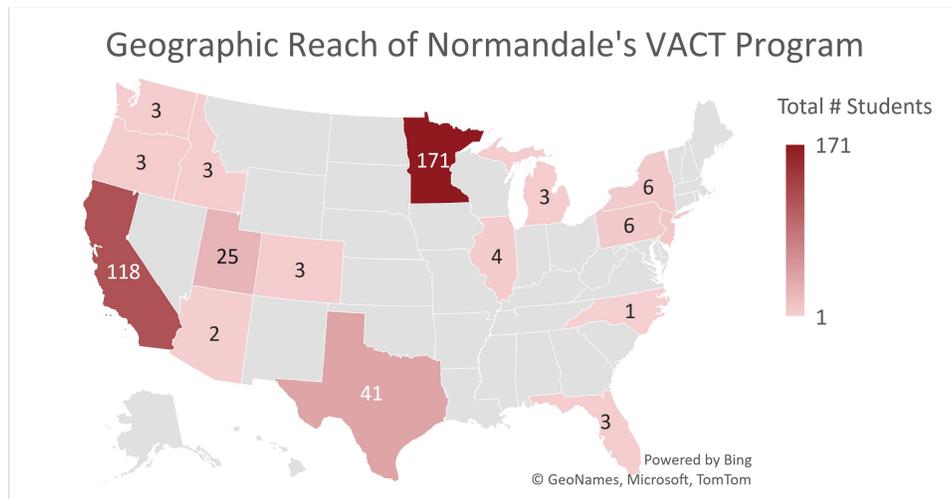


Figure 6 - Geographic Reach of NCC's VACT Program

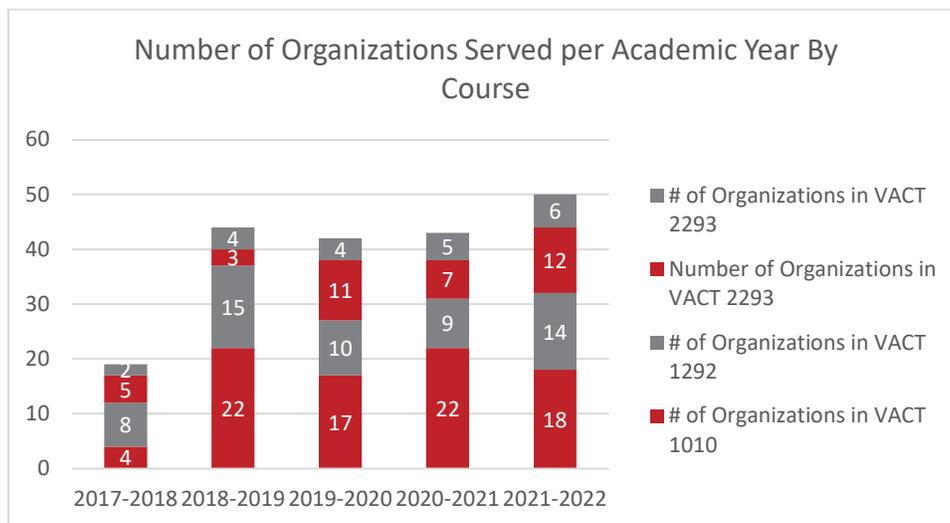


Figure 7 - Number of Organizations Represented by Course

Summary of Formative Outcomes
NCC successfully accomplished all of the major objectives of project DELIVER.
All of the major indicators are trending upwards, including:
<ul style="list-style-type: none"> • Enrollments (both total students and distance students) – Figure 4 • Completers – Figure 5 • Geographic reach of Normandale’s VACT program, currently reaching 13 states – Figure 6 • The number of businesses and organizations served by Normandale’s VACT program – Figure 7
The program saw significant improvements in both quality and quantity of physical resources and infrastructure.
The program saw positive collaboration and impact on multidisciplinary initiatives, specifically with the engineering technology program and the physical sciences.

Figure 8 - Key Formative Findings for Project DELIVER

Summative Outcomes

Overall, Project DELIVER achieved all if its desired outcomes. Normandale’s Vacuum Technology project team gaining extensive experience and significant lessons learned about successful practices for delivering technical learning through distance technologies, recruiting new instructors into technology programs, and supporting incumbent workers with education and training. In addition, the industry workshops conducted as part of this project provided valuable insight into the current state of vacuum technology education in the U.S. while providing validation of and opportunities for continuous improvement to Normandale’s curriculum.

The overall perception is that the project activities had a moderate to significant impact on the desired outcomes. The collective evaluation is summarized in Figure 9. The hands-on experiences and the blended delivery model got the highest ratings. The onboarding of new instructors had the widest range of responses. These findings are discussed in more detail in the following sections.

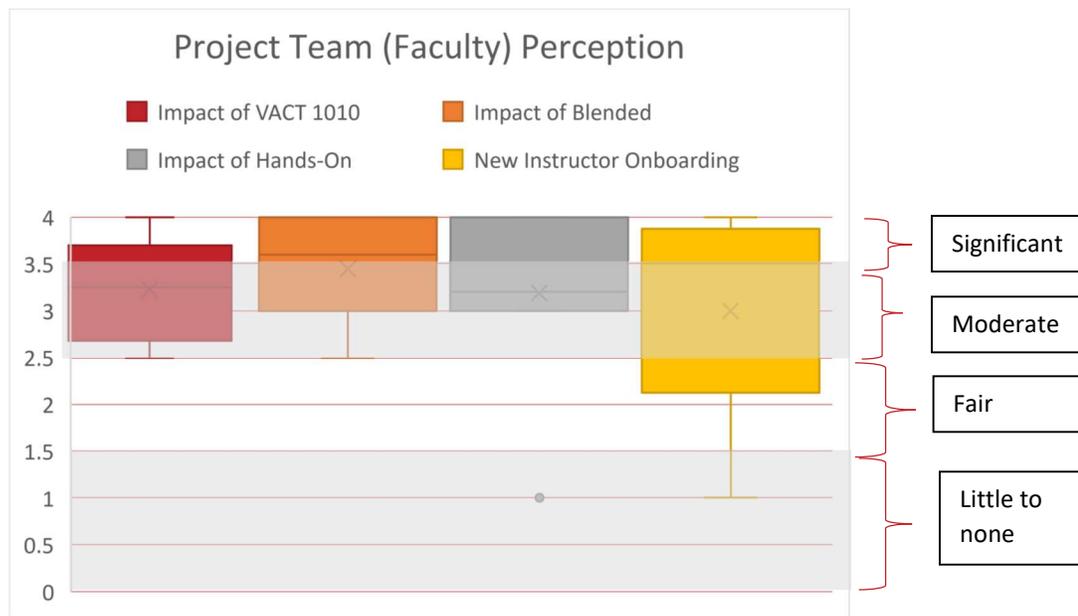


Figure 9 - Project Team Perception of Impact of Main Project Activities

Expand Pathways

The evaluation questions applicable to the impact on expanding pathways include the following:

EQ #1 – What were the motivating factors that attracted audiences to enter a course of study in vacuum technology?

EQ #2 - How effective is the Foundations in Vacuum Science course in preparing students for further courses in vacuum technology?

EQ #3 - How effective is the blend of synchronous and asynchronous teaching and learning platforms [and hands-on learning] in delivering complex STEM content and in preparing students for work in advanced manufacturing?

EQ #4 - What did we learn about the barriers and successes of integrating hands-on demonstrations and lab experiences into the curriculum?

The data sources used to evaluate these questions include:

- Student end of semester surveys (VACT 1010, VACT 1292/2293/2297, VACT 1194, VET)
- Project team interviews
- Faculty interviews
- Industry workshop and survey
- Pre and Post student test results
- Observations from NCC's Industry advisory group

EQ #1 – Motivation

Students reported that the most common reason for taking one or more VACT courses was related to career advancement at all levels. Students felt that the course or certificate would help obtain either an increase in wages or a promotion. The second most common reason was a recommendation from an employer or co-worker. (See Figure 10) This particular motivation was also consistent with comments from a student panel conducted on January 29, 2021 regarding their motivation to enroll in the VACT program. (See Figure 11)

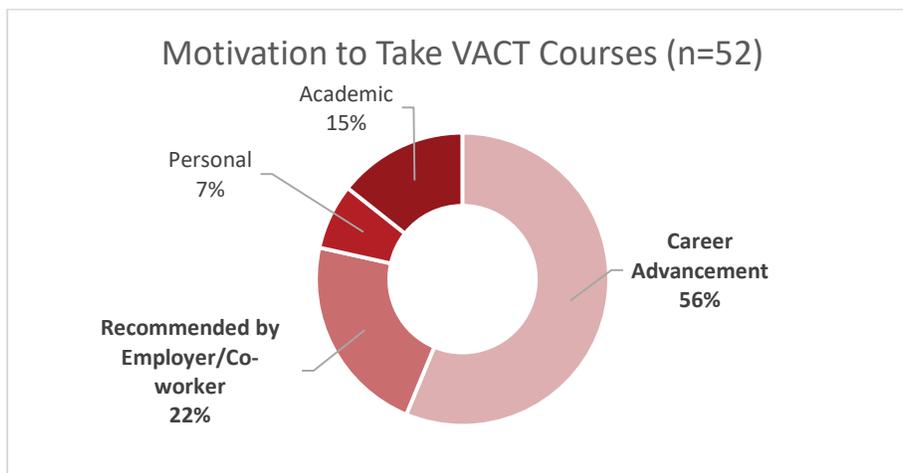


Figure 10 - Motivation for Taking VACT Courses

Motivation for Students to Enroll

- Take advantage of advancement opportunity
- Recommended by a supervisor or encouraged by management
- Part of an internship
- Encouraged by faculty

Motivation for Students to Persist

- Financial incentive in the form of a pay raise
- Desire to improve skills
- Promotion; path to management position

Figure 11 - Motivations to Enroll and Persist – Student Panel January 29, 2021

EQ #2 – Foundations in Vacuum Science

The DELIVER project team provided an average rating of moderate to significant impact of the Foundations in Vacuum Science course on the desired project outcomes (see Figure 12). Some of the key themes and specific observations from the project team are summarized in the table below.

Impacts of Foundations of Vacuum Science (VACT 1010) – Key Themes	Specific Observations
Course served best as a refresher - as opposed to introducing concepts to students for the first time.	<ul style="list-style-type: none"> • <i>Concepts in VACT 1010 were not new</i> • <i>Served as a good refresher to high school math and science needed in vacuum technology</i> • <i>Did not eliminate the need for addressing remedial math and science but reduced the amount of time needed in class to cover it</i>
Helped the new college learner adjust and adapt to a college environment and expectations	<ul style="list-style-type: none"> • <i>Class format was supportive of the new-to-college student</i> • <i>Increased the accessibility of college level class for those that have been out of school for a while</i> • <i>Reduced the stress of many students</i>
Effective in addressing the needs of incumbent workers	<ul style="list-style-type: none"> • <i>Majority of students were already fully employed and not from an academic background</i> • <i>Introduced incumbent workers to the role of a college student</i> • <i>Practical applications of math and science concepts work better for incumbent workers</i>

Figure 12 - Key Themes and Specific Observations from Project Team re VACT 1010

Student perceptions from interviews and surveys supported a similar positive finding (see Figure 13 through 15)

- **70% of surveyed students agreed or strongly agreed** with the statement that “VACT 1010 improved their understanding of math concepts.”

- **80% of surveyed students agreed or strongly agreed** with the statement that “VACT 1010 improved their understanding of chemistry concepts.”
- **78% of surveyed students agreed or strongly agreed** with the statement that “VACT 1010 improved their understanding of vacuum technology concepts.”
- **80% of surveyed students agreed or strongly agreed** with the statement that “VACT 1010 improved their understanding of science concepts.”
- **81% of surveyed students** said that VACT 1010 met or exceeded their expectations.
- **81% of surveyed students** said that they would recommend VACT 1010 to other students.

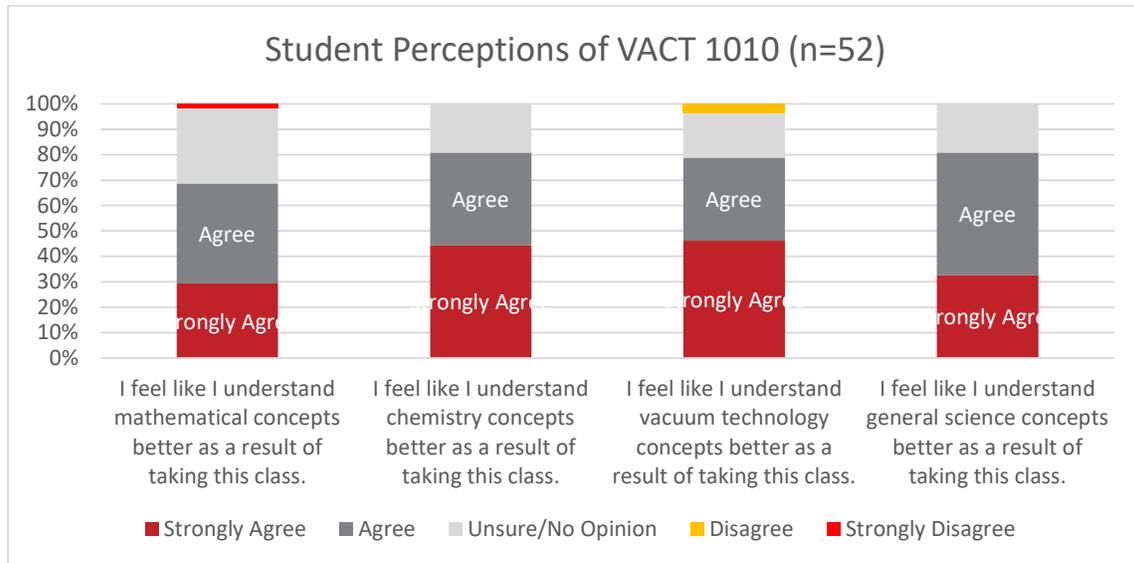


Figure 13 - Student Perception of the Impact of Foundations in Science

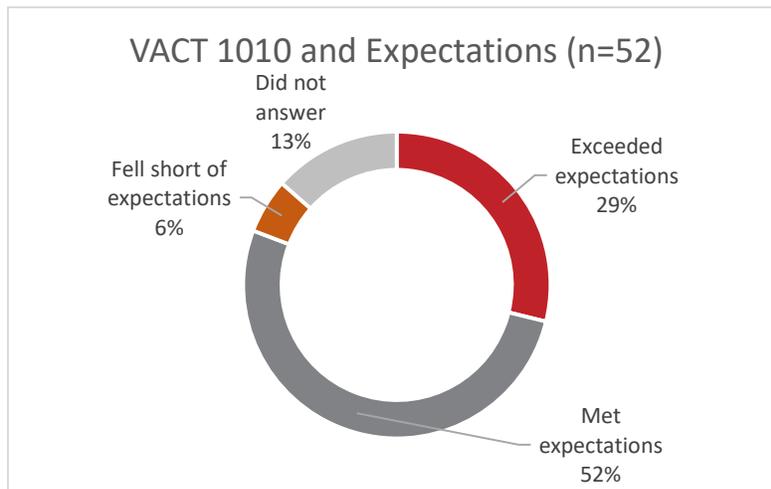


Figure 14 - Student Expectations for VACT 1010

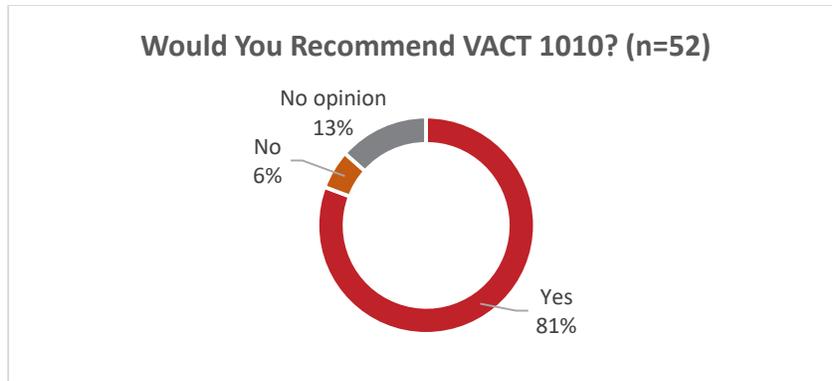


Figure 15 - Recommend VACT 1010 to Other Students

Pre and post testing of students also supported the finding of positive impact on student learning. (See figures 16 a through c). A summary of these test results showed a:

- **43% increase** in math scores after taking VACT 1010
- **78% increase** in chemistry scores after taking VACT 1010
- **65% increase** in overall scores after taking VACT 1010
- **86% increase** in overall scores after taking VACT 1292

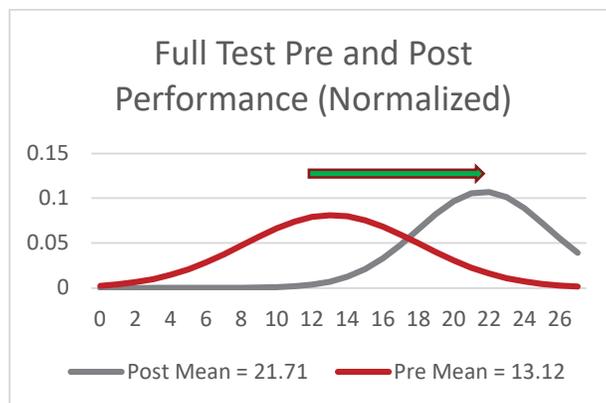
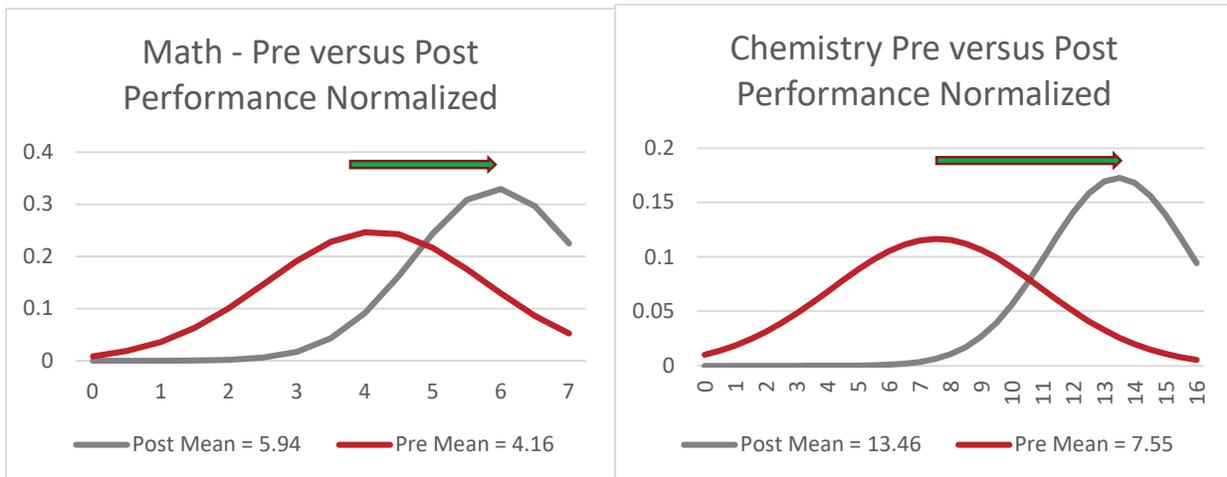


Figure 16 (a-c) - Pre and Post Student Performance VACT 1010 (n=101)

There did not seem to be an appreciable difference in test results between those students that took the eight-week version of VACT 1010 and those that took the 16-week version of the course. (see Figure 17)

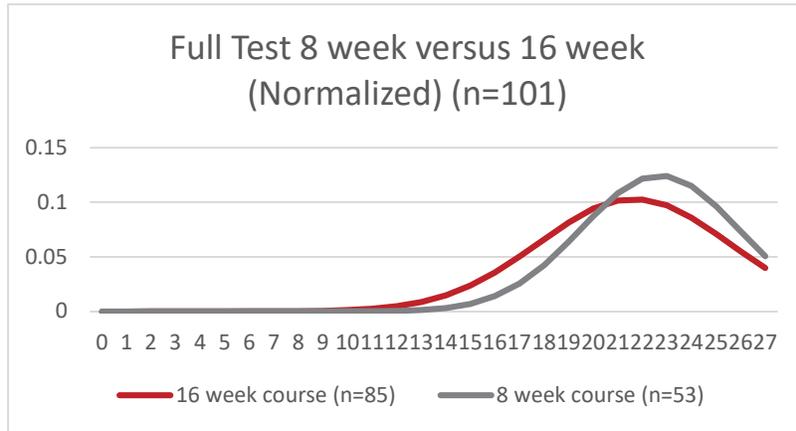


Figure 17 - Post VACT Student Performance - 8 week versus 16 week

In addition to measuring student outcomes in VACT 1010, the project administered both a pre and post concepts inventory test in VACT 1292 during three semesters (fall 2020, spring 2021 and fall 2021). This test looks at the course learning objectives for VACT 1292 and contained 23 multiple choice questions. The results are summarized in Figure 18 below. The overall results indicate that VACT 1292 is very successful in teaching the stated course objectives. Pre-semester the average student score was 47.7%, which would be a failing grade on a standard grading range. The average post-semester score was 88.9%, which is nearly twice the pre-test score and would be a very high B grade.

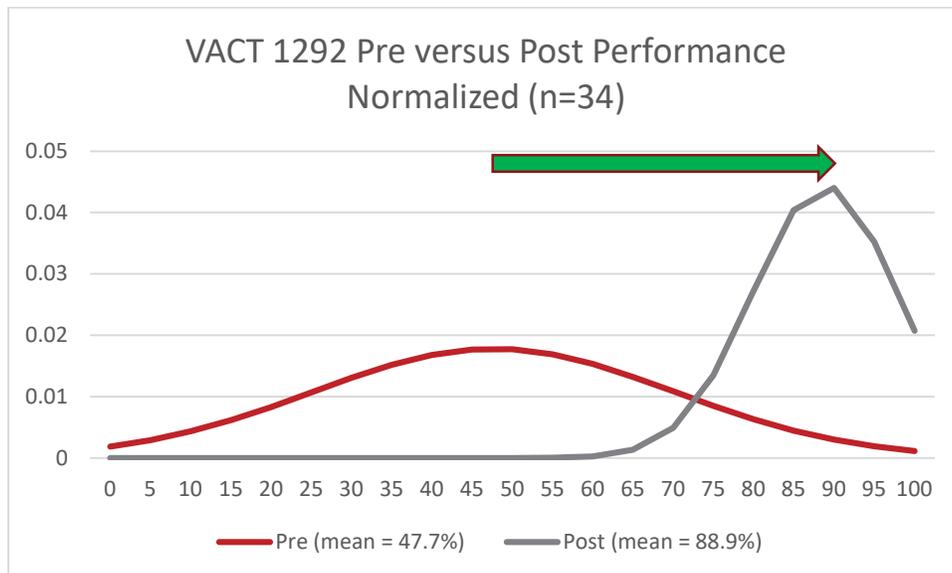


Figure 18 - Pre and Post VACT 1292 Student Performance

EQ #3 – Blended Model

There were varied definitions among those interviewed for a “blended model” delivery model. Some of these definitions included such characteristics as:

- Flipped classroom – homework before class
- Active learning – learning by doing
- Mix of physical and virtual students in a synchronous environment
- Blend of synchronous and asynchronous learning

The impact of using a blended model was perceived as mixed. There were both benefits and challenges identified with this delivery model (summarized in Figure 19 below).

Benefits of Blended Model	Challenges of Blended Model
<ul style="list-style-type: none"> • <i>Active learning improved understanding of concepts</i> • <i>Incumbent workers were more motivated by learning by doing</i> • <i>Incumbent workers were able to learn concepts in context</i> • <i>The utilization of the Vacuum Equipment Trainers (VET) resulted in higher engagement from students</i> 	<ul style="list-style-type: none"> • <i>Required a higher level of instructor preparation</i> • <i>Managing the equipment</i> • <i>Virtual student was less likely to ask for help when needed</i> • <i>Format places more responsibility on the student for learning</i> • <i>Technology problems resulting in degraded quality of audio and video</i> • <i>Work schedules of students often conflicted with class</i> • <i>Cheap technology at the user end resulted in lower quality</i> • <i>Online students are often more passive than classroom students</i> • <i>Designing lab activities that fit into time constraints</i> • <i>Logistics of shipping trainers to remote sites</i>

Figure 19 - Benefits and Challenges of Blended Delivery

Some of the key findings include:

- Roughly **90% of students** felt that their expectations for the blended model approach were met or exceeded. (Figure 34)
- However, when looking at the general categories of the quality of the class, the ability to develop community among students and whether the student would recommend or repeat the experience, roughly **only 50% said that the experience was positive or strongly positive** in providing these outcomes. In fact, a significant number of students were unsure or had no opinion on these criteria. (Figure 20)
- The **top positive aspects of the classes** were the technical content and knowledge, skills and abilities obtained, the quality of instructors and the hands-on experiences (see Figure 21). Some student comments that support these aspects include
 - Instructors
 - *“The one on one make ups that Nancy did for our group were by far the most useful part of this course. Nancy is an amazing educator and I would strongly suggest her to ANY person taking Vacuum science courses or wanted to gain more knowledge”*

- *“I found it fascinating to remotely control our vacuum system from our own homes. Tom was very helpful in guiding us through the process if we had any questions.”*
 - Building Knowledge, Skills and Abilities (KSA)
 - *“I also enjoyed how he often related the lecture/class discussions to every day topics/items, it made lectures much more relatable and easier to understand.”*
 - *“Learning more about cryo pumps which I work with on the field, and also having a more in depth understanding of cold cathodes and magnetron processes.”*
 - *“I find it all interesting because it relates to my job.”*
 - Hands-On
 - *Found the most benefit to be “In labs where we were actually using the equipment”*
 - *72% of students said that the number of hands-on activities was “just right” (Figure 25)*
- The **most often mentioned negative aspects** were the teaching materials and typical issues found with remote learning and technology issues (Figure 23). These negative aspects were more difficult to analyze due to a wider range of comments and observations from stakeholders.
- The relationship that had the most impact on student success was still with the instructor. Over **80% of students surveyed agreed or strongly agreed** with the statement that “the instructor cared whether I learned the material” (Figure 24)

Regardless of the specifics of the delivery model, feedback from students and faculty identified the following key criteria for student success:

- Amount of background of the student coming in is important
- Motivation of the student is a key indicator of success
- Quality of technical content and instructor is more important than the delivery method

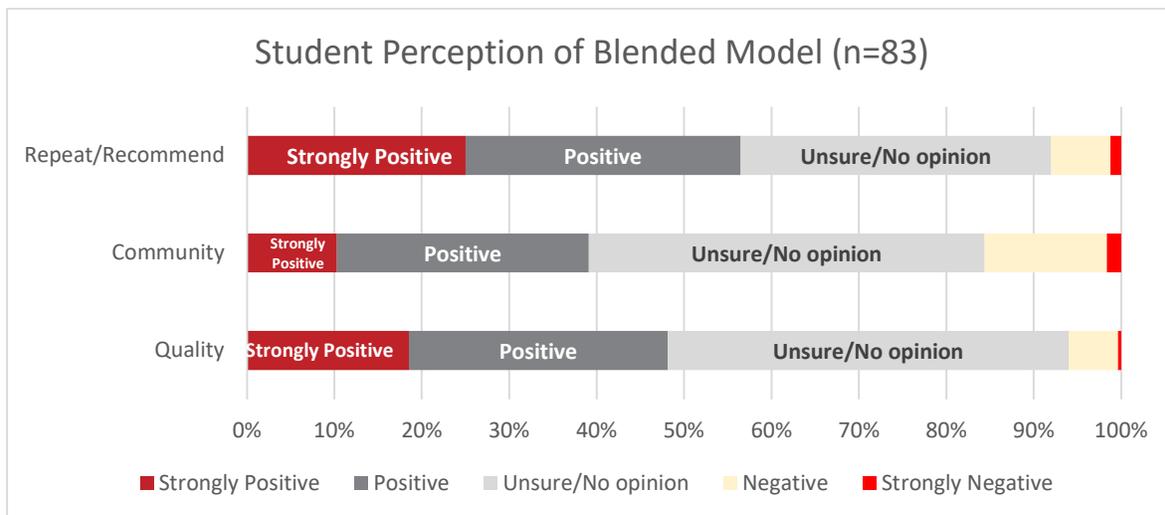


Figure 20 - Student Perceptions of Blended Model

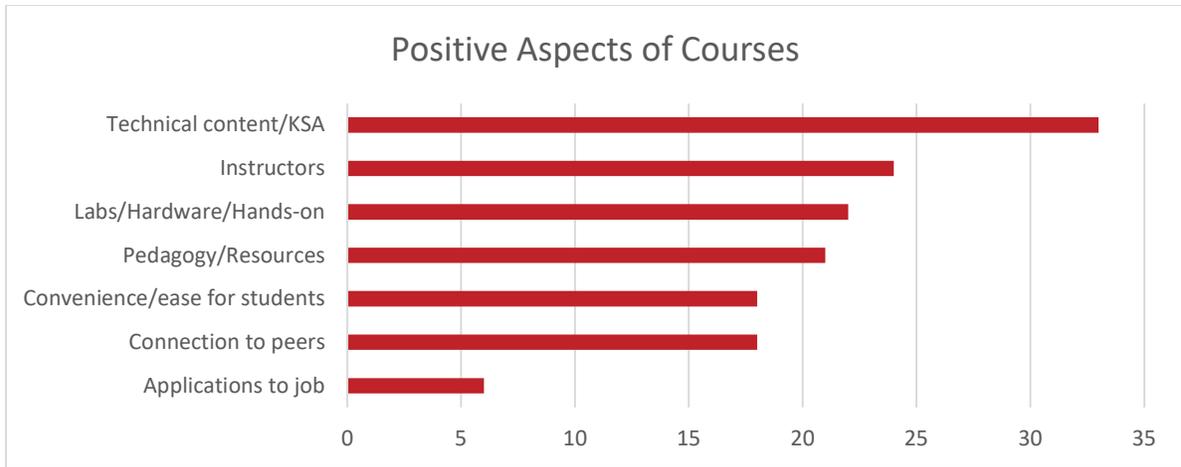


Figure 21 - Positive Aspects of VACT Courses

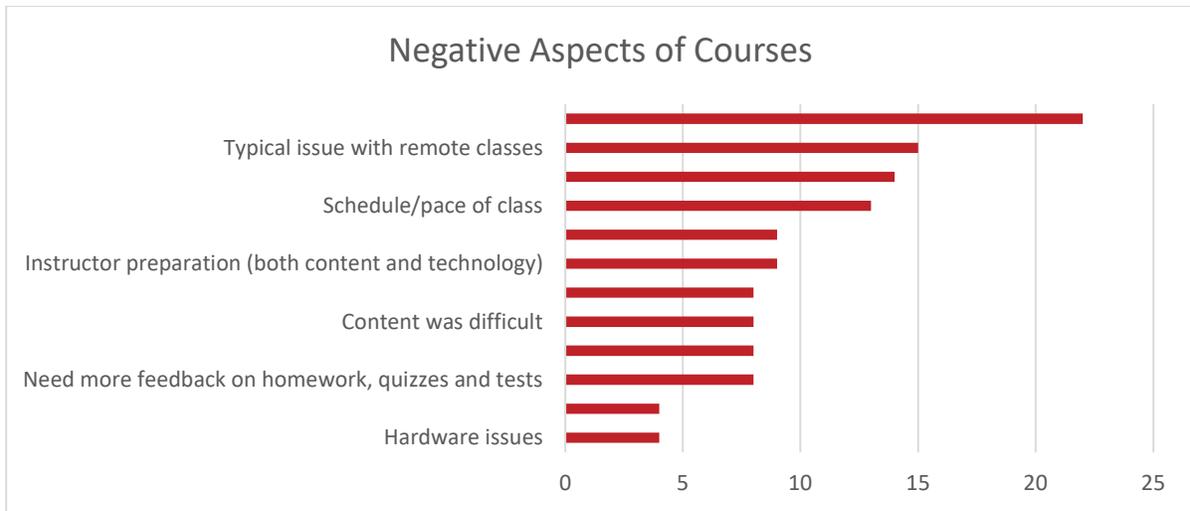


Figure 22 - Negative Aspects of VACT Courses

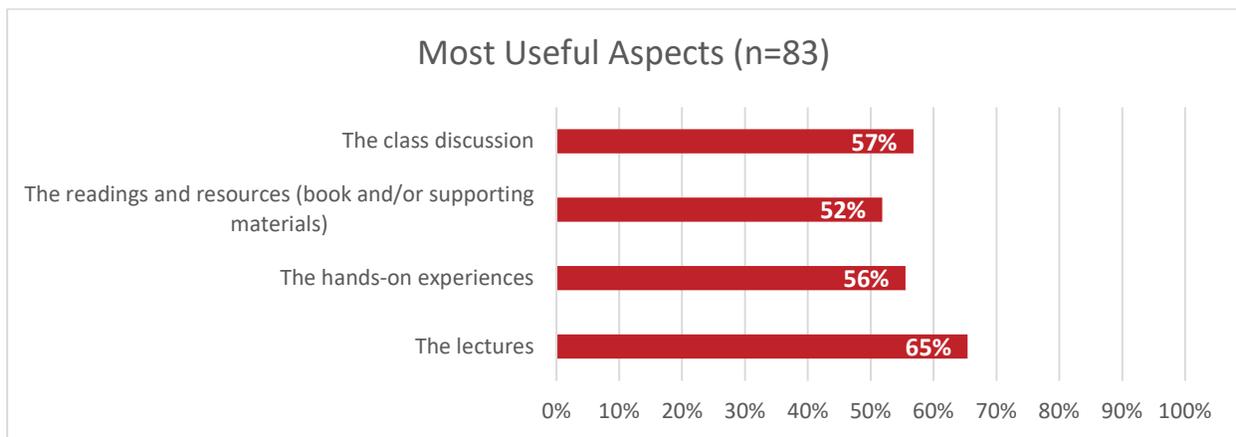


Figure 23 - Most Useful Aspects of Blended Model

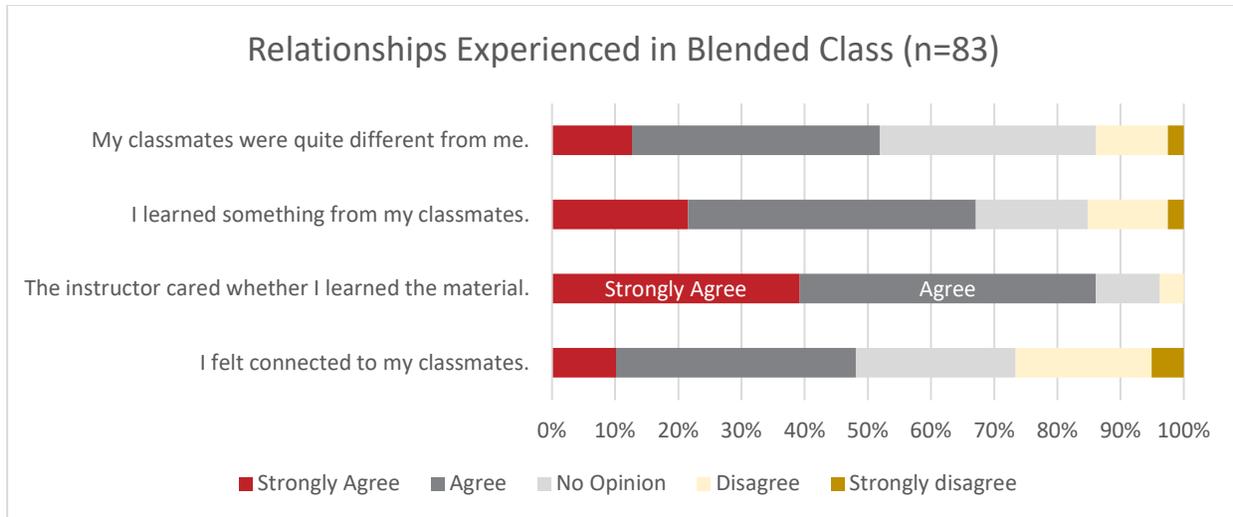


Figure 24 - Relationships Experience in Blended Classroom

EQ #4 – Vacuum Equipment Trainers

A significant new addition to Normandale’s vacuum technology program under the NSF REVAMP and DELIVER projects has been the use of vacuum equipment trainers (VET) to support hands on experiences for both in-class and remote students.

VET systems were used extensively to support teaching and learning in the VACT 1292, VACT 2293 and VACT 2297 courses. The VET systems support progressively more complex learning activities in each course. Initially these trainers were shipped out to sites where remote learners taking the class through distance learning technology could experience direct hands-on operation of a vacuum system. By the end of the project distance students were utilizing a remote automated VET, where students could remotely operate the system located in NCC’s lab directly through an HMI system.

A strong theme found in the evaluation is the steep learning curve for integrating the trainers into the VACT program. Some of the issues identified by faculty and students include:

- How to best incorporate the VET into the curriculum – a continuous review and modification of all activities has been needed to optimize the results
- How to ensure adequate student preparation for operation of the VET system
- Instructors need to be more aware of the concepts that students struggle to master so that the use of the VET can be optimized to specifically target these concepts

While there was a definite learning curve for the implementation of these VET systems into the course curriculum, the overall results were still positive.

- **72% of students** found the number of hands-on activities to be just right (Figure 25).
- **86% of students** saw some positive impact on their ability to learn the course objectives. **57% of students** said the VET significantly improved their ability to learn the course objectives (Figure 26).
- **86% of students** saw some positive impact on their ability to develop workplace skills. **57% of students** said the VET moderately to significantly improved the development of workplace skills (Figure 26).

- **90% of students** saw at least some improvement in their learning experience from the VET systems. **76% of students** said the remote operated VET systems somewhat to significantly improved their learning experience (Figure 27).

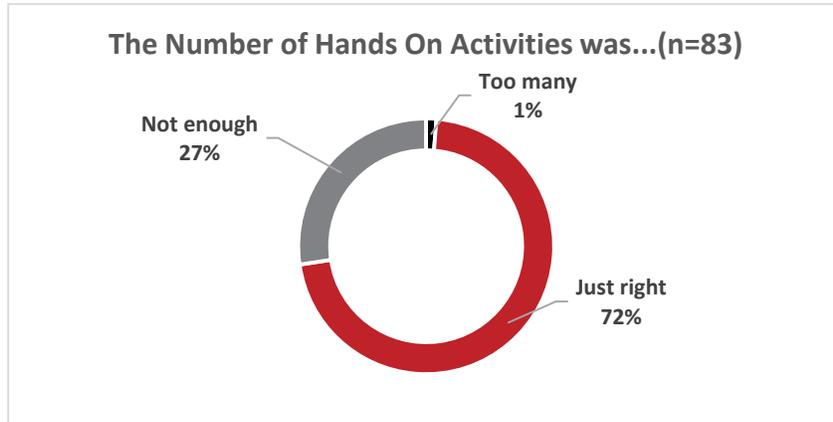


Figure 25 - Student Perceptions of Quantity of Hands On Experiences

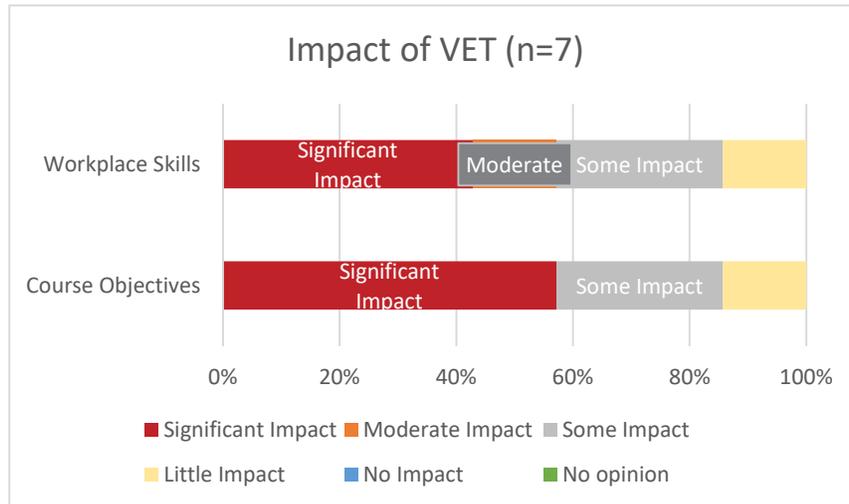


Figure 26 - Impact of VET Systems on Learning

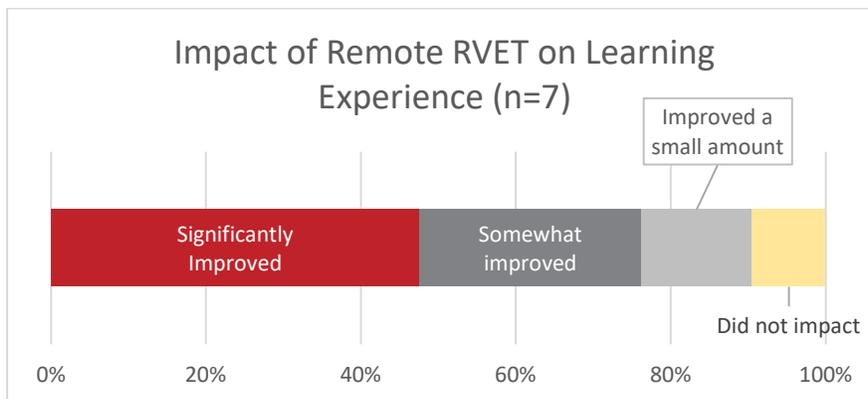


Figure 27 - Impact of the Remote Operated VET on Student Experience

Students and faculty identified both positive impact from the VET systems as well as some challenges.

Benefits	Challenges
<ul style="list-style-type: none"> • Trainers have been a “game changer” for the VACT program. • Technicians learn concepts better by doing. • Hands-on activities have helped instructors better understand which concepts are most problematic to teach and learn. • Hands-on activities improve problem solving and troubleshooting skills. • The addition of the trainers has helped break down the educational process to manageable segments. By the time the student reaches the final course they are seeing vacuum systems very close to what they see in industry. 	<ul style="list-style-type: none"> • Managing the condition of both hardware and software at the receive sites. • Standardizing data collection between local and remote options. • Students not being present for labs. • Teaching, coaching and problem solving from a distance. • Shipping – scheduling, protecting the condition of the equipment.

Figure 28 - Benefits and Challenges of the VET Systems

Some positive comments include:

- *“It allows the student a visual representation of vacuum processes”*
- *“It helped very much to have the instructor point out the various parts of the system and see how they all work together. This was especially true for me when we were discussing leak detection. Being able to see the process really helped.”*
- *“I could tell that students that had an opportunity to work with an actual system picked up the content quicker.”*

The primary challenges identified with the VET systems include:

- *“My fall 2021 and spring 2022 students haven't shown a lot of enthusiasm to use the system and click the valve buttons on and off. Some parts are still a work in progress, such as the gas conductivity lab, MFC attachment. There isn't a whole lot for them to interact with either on ARVET system either, except to turn the roughing or vent valves on and off.”*
- *“Because of online training, at times, the instructor had difficulty operating the VET and the audio/visual equipment at the same time. This wasted class time as well. “*
- *“I am still learning how to make VACT 1292 more engaging and interesting for my students so it feels less passive for them.”*

The barriers and obstacles encountered with use of the VET systems, in order of their frequency of mention, are:

- 1) Remote operation is still not as useful as in-person, hands-on experience
- 2) Technology issues sometimes resulted in wasted or dead time during class
- 3) Hardware compatibility issues
- 4) Objectives for how to use the VET were not always clear

Interviews with NCC’s industry advisory board also yielded some insight into the value of the VET systems:

- “A variety of experiences are crucial for training vacuum technicians. I think the ability to access vacuum trainers remotely is a tremendous capability and one that should be explored in as great of detail as possible!”
- “The VET was very well received by our distance learning students.”
- “I am in favor of remote operation of Vacuum Chambers as many systems in industry are now operated via remote or at the very least HMI machine centers.”

Other Activities Impacting Expansion of Pathways– Student Support Liaison, COVID and Industry Workshops

There were other activities or issues that were identified after the project started that impacted the desired outcome of expanding pathways. These include:

- Pilot program for a student liaison support position
- Impact of the COVID pandemic on the student experience
- Industry workshops

Student Support Liaison Position

With support from the grant, NCC retained a part-time Student Support Liaison position to assist with managing the network of industry contacts, recruiting and onboarding new students (especially incumbent workers), and assisting students with the Vacuum Technology Certificate application process. All of the students who utilized this dedicated support saw moderate to high value of working this position, with 85% seeing a high value from this support. (Figure 29)

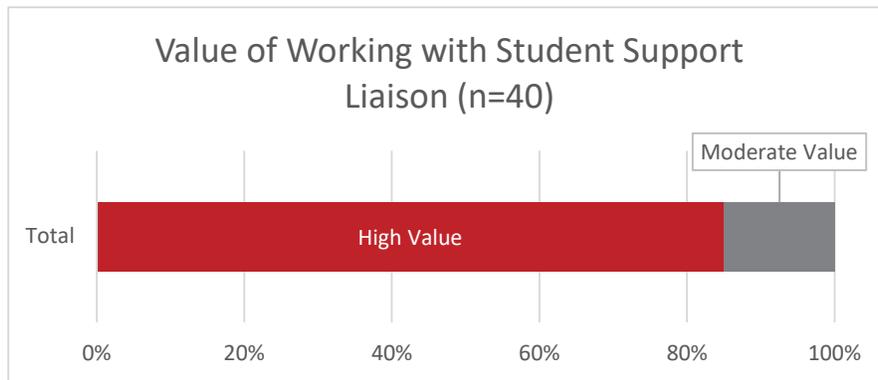


Figure 29 - Value of the Student Support Liaison

Impact of COVID

The COVID pandemic had broad impacts on the project and higher education in ways that will not be fully understood for many years. In the short term, the college had to restrict access to classroom spaces on campus from the spring of 2020 through the spring 2022 term. The changing economic conditions during this period, especially more competitively-paid external internship opportunities available to students, made it more challenging to recruit students. The project gathered feedback from several of the vacuum technology students in this project to garner some idea of this impact. Between 30% - 40% of students reported impacts across a variety of issues. (See Figure 30).

- The largest impact was on the students’ personal lives, with 47% reporting a moderate to significant impact.

- The second and third areas mentioned include “impact on my job” (43% with 29% reporting a significant impact) and on the quality of classroom instruction (43% reporting a moderate to significant impact).
- Interestingly, the least impact was on the student’s ability to stay motivated for the course, with only 18% reporting a moderate to significant impact on this issue.

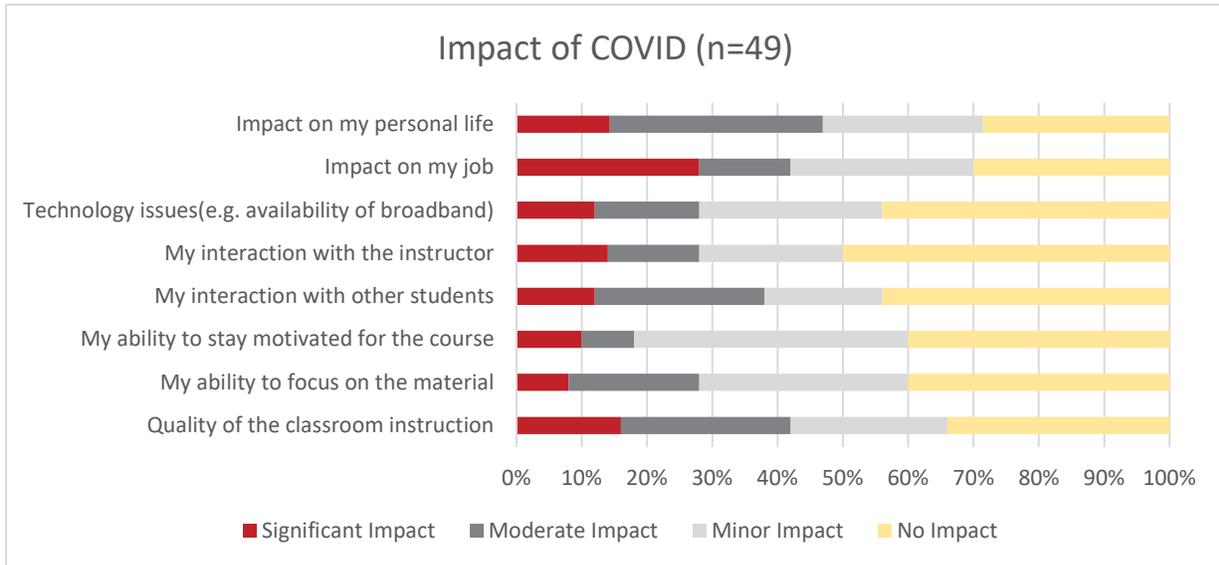


Figure 30 - Impact of COVID

Industry Workshops

NCC offered several one-day workshops between 2021 and 2022 on the fundamentals of vacuum systems to industry groups and industry employees. These workshops were a strategy to increase awareness of the NCC vacuum technology program and to encourage increased enrollments. These workshops were well received. While the quantity of participant feedback was limited, it did indicate that they did increase exposure to NCC programs and identified an opportunity for future workshops. Their impact on potential enrollments was not as strong.

- 83% of attendees said the workshop was better to much better than expected (Figure 31)
- 100% of attendees said they were likely to much more likely to take future workshops (Figure 32)
- However, 67% of attendees said they were neither more or less likely to enroll in NCC’s VACT certificate program (Figure 33)

A sample comment from one of the industry partners also highlights a need for shorter, customized training.

- *“Have you ever considered a customized class for techs in the industry already? Possibly at the customers site or a class at Normandale with just that company’s employees in it? For example we do a troubleshooting class at a local college that students attend 1 day per week for 2 hours and it is just our technicians.”*

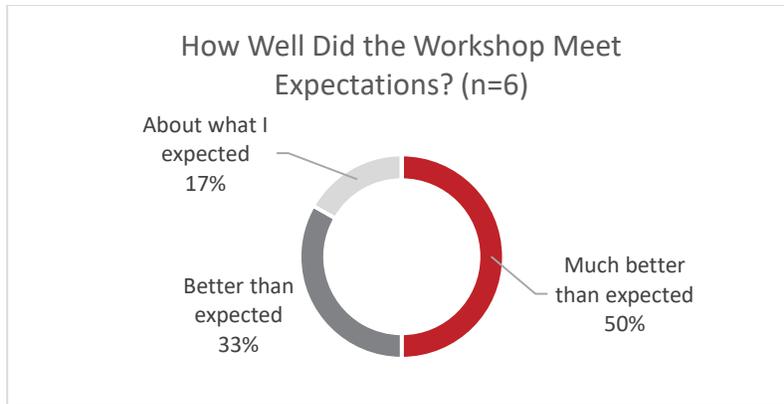


Figure 31 - Industry Workshops Met Expectations

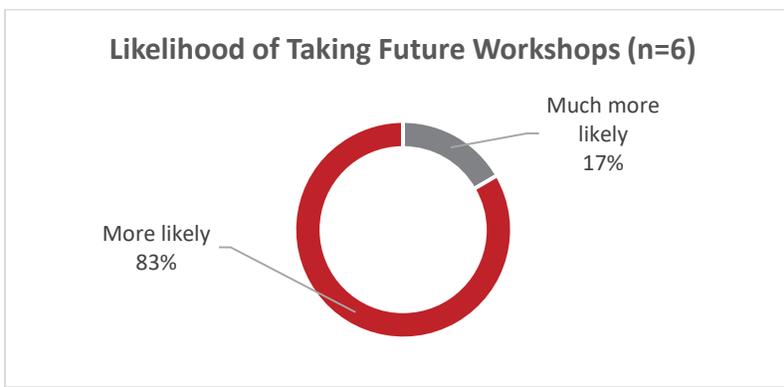


Figure 32 - Impact of Workshops on the Likelihood of Taking Future Workshops

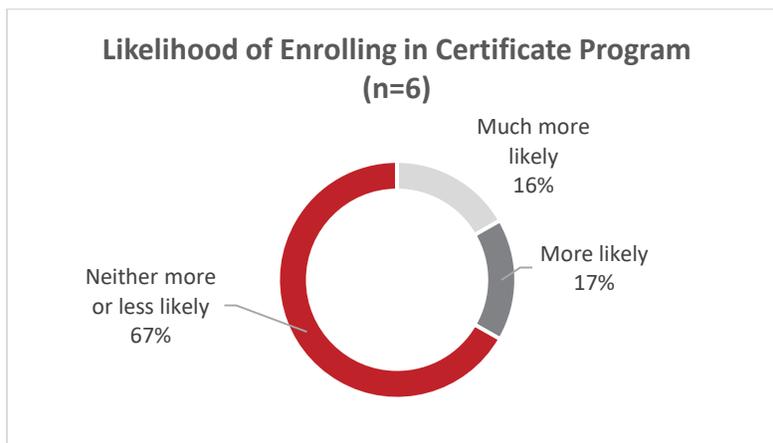


Figure 33 - Impact of Workshops on Likelihood of Enrollment in Certificate Program

Key Findings - Expanding Pathways

EQ #1 – What were the motivating factors that attracted audiences to enter a course of study in vacuum technology?

- The primary motivation for students to take a vacuum technology course is the desire for career advancement

<ul style="list-style-type: none"> • This finding would suggest that the primary marketing and outreach target audience would be through industry partners
<p><u>EQ #2 – How effective is the Foundations in Vacuum Science course in preparing students for further courses in vacuum technology?</u></p> <ul style="list-style-type: none"> • Both the NCC Project team and participating students perceived the Foundations in Vacuum Science course to be very effective. • Pre- and post-test performance data supports that perception.
<p><u>EQ #3 – How effective is the blend of synchronous and asynchronous teaching and learning platforms [and hands-on learning] in delivering complex STEM content? How effective is the blend of synchronous / asynchronous in preparing students for work in advanced manufacturing?</u></p> <ul style="list-style-type: none"> • Results are mixed • Key indicators for success are the amount of background of the student coming in and the motivation of the student • Quality of technical content and instructor is more important than the delivery method
<p><u>EQ #4 - What did we learn about the barriers and successes of integrating hands-on demonstrations and lab experiences into the curriculum?</u></p> <ul style="list-style-type: none"> • There is a steep learning curve attached to the implementation of VET systems into the courses and curriculum • VET systems still had a positive impact on providing quality hands-on experiences to students
<p><u>Other activities – Student Support Liaison, COVID, Industry Workshops</u></p> <ul style="list-style-type: none"> • All of the students who utilized this support saw moderate to high value of working this position, with 85% seeing a high value from this support. • The largest impact of the COVID pandemic was on the student’s personal life • Industry workshops did not have much impact on future enrollment in credit classes but had a significant impact on identification of potential for customized training and industry engagement

Meet the Education and Credential Needs of Students and Businesses

The evaluation questions for this specific impact were:

- EQ #5 - Is a focused track credential able to meet industry needs for skilled vacuum technicians?
- EQ #6 - What is the current state of vacuum technology instruction in the US?

The data sources used to evaluate these questions included:

- Feedback from students
- Observations from the NCC vacuum technology industry advisory group
- Industry workshop results and survey
- Industry Workshop report

EQ #5 – Focused Track Credential

The feedback from students on the program has been extremely positive. When asked how the courses and programs met their expectations, over 90% said that every course in the certificate program met or exceeded their expectations. (See figure 34)

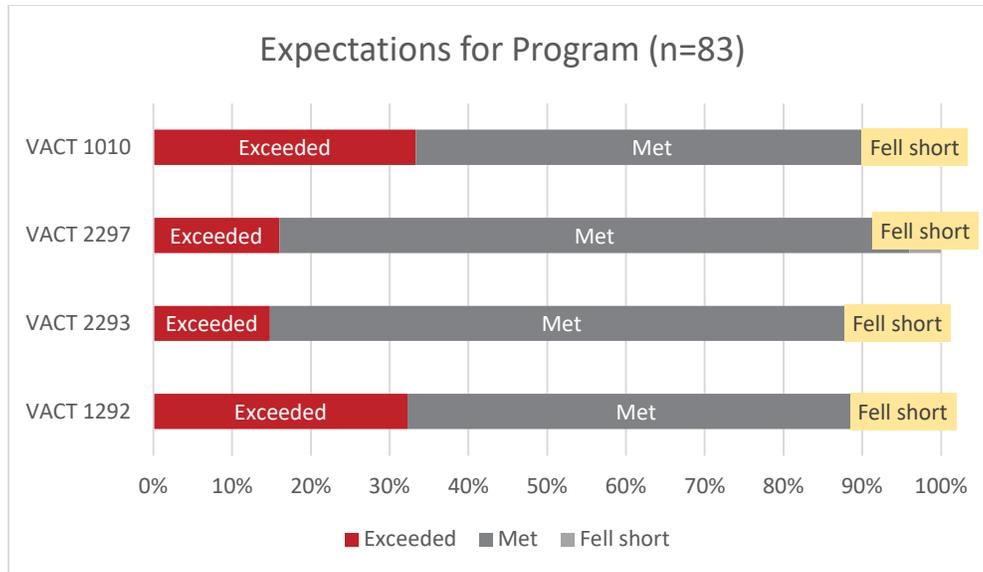


Figure 34 - Student Expectations Met

Specific comments from students supported this perception.

- “I really believe that the training you all put together is a phenomenal curriculum. The beginning is bare bones basic, and I believe that to have some very solid worth because as we progress in anything we tend to forget bits and pieces of the basics. So going through this and revisiting the basics was great. Normandale does a fantastic job of covering need to know topics and their higher level courses have immediate worth in the work place. Even though I’m not the HMI person at my facility the knowledge of how, what and why has been extremely valuable for me in my job. There’s a reason I’ve continued to try and continue my education with you all and this course work truly shows how great and innovating Normandale’s STEM department is.” (NCC Vacuum Technology Student)*
- “The Vacuum Technology program has served me well in my career at a National Laboratory. The program provided me with a strong foundation to leverage my on the job training and become instrumental in our Laboratory’s thin film capabilities. Not only that, the program has allowed me to open a pathway to lead vacuum technology in our organization”. (LLNL Employee)*
- “It has been a few years since I have completed and become a Certified Vacuum Technologist but the course work has led to many opportunities for me and for others that I now manage. Once I completed the Normandale courses I was tasked with being the vacuum technologist in support of our OSL lab which I did for about a year until they hired a full-time person as this was not classified as one of my responsibilities. I have since become a supervisor and have been asked to mentor/tutor some of the students who have taken or are taking the course. I also have two of my direct report employees who I have sparked interest in the course. Their feedback is positive and they strive to get their certification. The lab recognizes their achievements and like me, will eventually be compensated with a pay increase because of their improved skills, knowledge, and abilities”. (LLNL Employee)*

EQ #6 – Current State of Vacuum Technology Education

As part of the NSF-ATE DELIVER (Distance Education and Learning in Vacuum Technology) project, Normandale Community College (NCC) hosted a series of five virtual workshops between September 2020 and March 2021 that focused on shaping the future of vacuum technology education and training.

Workshop participants (right) included key stakeholders from related industry professional societies, industry partners, higher education, vacuum technology faculty from two-year institutions, former students of the Vacuum Technology Program, and the National Science Foundation. The goal was for participants to gain a deeper understanding of existing education opportunities in vacuum technology and to describe their role in shaping the programs within industry and higher education that are driving workforce development in vacuum technology.



These workshops sought to

- 1) Increase understanding of the current state of vacuum technology education in the U.S.
- 2) Anticipate and plan for enrollment trends among different market segments
- 3) Support the evaluation process of the National Science Foundation's (NSF) DELIVER project

The key outcomes from the workshop series are discussed in detail in the workshop report¹ and include:

- 1) A high-level strategic analysis that identified five programmatic categories for further investigation by workshop organizers and participants
- 2) A problem map that explores the underlying issues for these identified gaps in vacuum technology education
- 3) Industry panel providing their perspective on the state of vacuum technology education
- 4) Student panel providing their perspective on the state of vacuum technology education
- 5) A solutions tree that provides a list of possible initiatives to address the identified gaps in vacuum technology education
- 6) Background documents and recordings for all of the virtual workshops posted to the project website: <https://www.normandale.edu/departments/stem/vacuum-and-thin-film-technology/shaping-the-future-of-vacuum-technology-education>

During these workshops, participants identified and ranked technical topics important to vacuum technology technicians. The results confirm that NCC's Vacuum Technology Certificate curriculum addresses most of these critical topics (see Figure 35). It is worth noting that the topics not covered tend to be specific equipment maintenance issues, which are usually better suited to company-specific training programs.

¹ "Shaping the Future of Vacuum Technology Education: 2020-2021 Workshops"; Outcomes Consulting Services for Normandale Community College, June 30, 2021

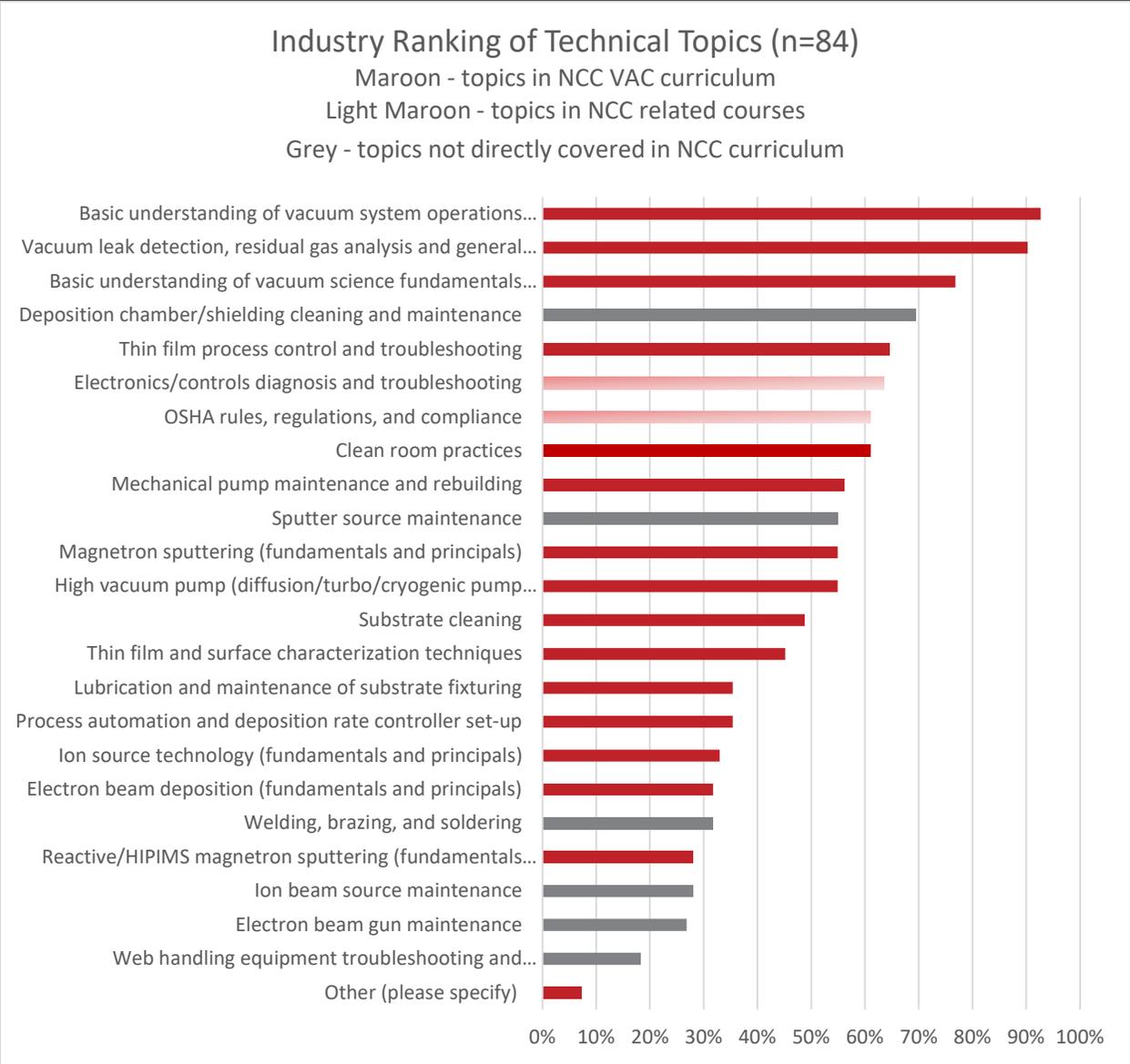


Figure 35 - Industry Ranking of Technical Skills Needed (Industry Workshops)

In preparation for the most recent NCC vacuum technology Industry Advisory Board meeting during the spring of 2022, advisory board members were similarly asked to identify and rank technical topics needed by vacuum technicians. The results mirrored those from the industry workshops and confirmed that all of the key topics were included in NCC’s certificate program.

The industry workshops included a high-level strategic analysis that identified five programmatic categories for further investigation by workshop organizers and participants (Figure 36):

- 1) **Programs:** Identify the processes and partnerships that would maintain or grow a vacuum technology education program at different types of organizations (academic, non-profit) such as marketing, onboarding, and developing new credentials.

- 2) **Resources:** Identify the broad range of needs and interdependencies that impact the delivery of vacuum technology education such as funding, program advocacy, recruiting and onboarding new instructors, content delivery methods / platforms, lab experiences with both academic and workforce-ready outcomes, equipment, materials and supplies, procurement, technical and administrative support staff, and promoting and maintaining workforce-related relationships and partnerships.
- 3) **Low enrollments:** Identify the challenges and solutions to achieving sufficient enrollment levels to sustain the Vacuum Technology program at Normandale.
- 4) **Opportunities:** Explore initiatives such as establishing new strategic partnerships between stakeholders invested in vacuum technology education (two-/four-year academic institutions; professional societies; research and industry organizations); and identify target markets or audiences for careers in vacuum technology
- 5) **Knowledge gaps and synergies:** Identify knowledge gaps in existing education curriculum (from Normandale) or training topics (from professional societies or industry) and also identify the potential synergies or content pathways between organizations that provide education and training opportunities.

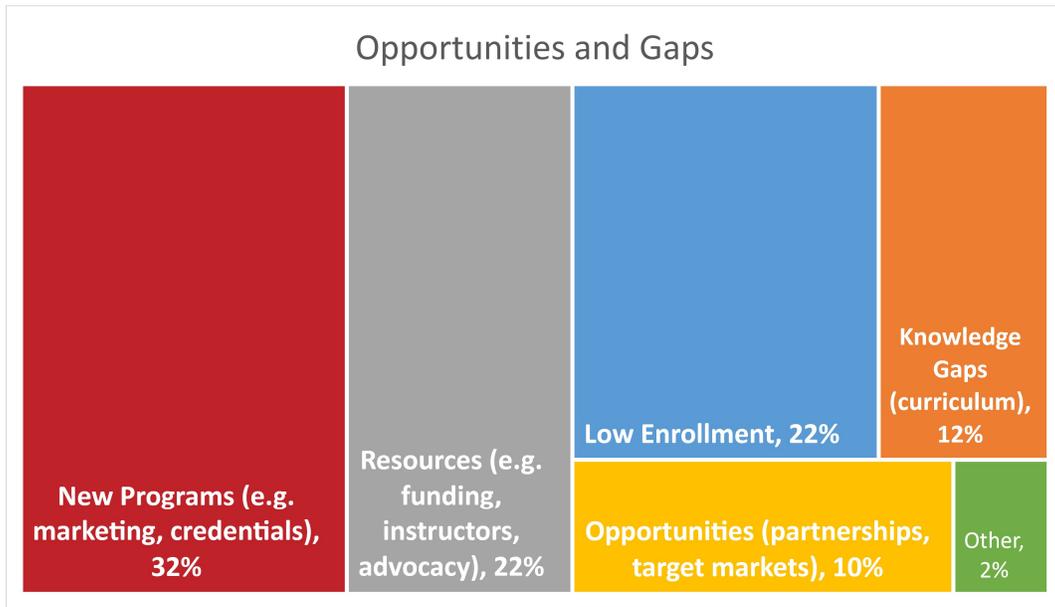


Figure 36 - VACT Program Opportunities and Gaps

Finally, the result of the industry workshop was a series of “solution trees” that identified some possible strategies and tactics that could be employed to address these opportunities and gaps. These solutions trees are summarized in Figure 37 below.

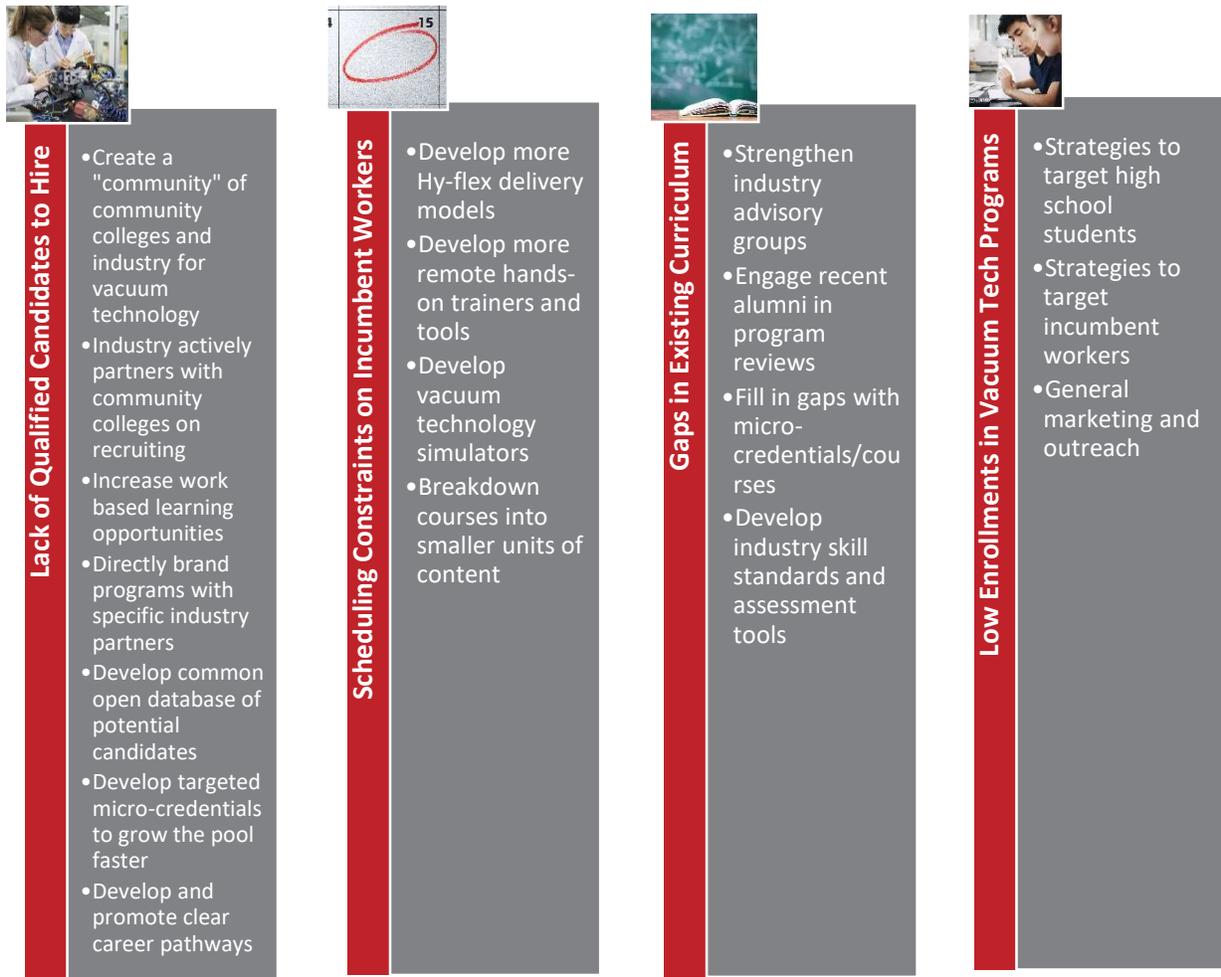


Figure 37 - Solution Trees - Possible Strategies and Tactics

These solution trees were used in small group discussions from NCC's May 6, 2022 advisory group to generate some brainstorming and feedback on strategies to address the findings from these workshops.

Key Findings – Meet the Needs of Students and industry	
EQ #5 – Is a focused track credential able to meet industry needs for skilled vacuum technicians?	<ul style="list-style-type: none"> • Normandale's vacuum technology program meets or exceeds the expectations of industry and students • Normandale's certificate program covers the critical knowledge, skills and abilities needed by vacuum technicians
EQ #6 – What is the current state of vacuum technology instruction in the US?	<ul style="list-style-type: none"> • There are still opportunities and gaps in vacuum technology education that could be addressed. • The industry workshops conducted under the DELIVER project did a good job of identifying and prioritizing these opportunities and gaps

Attract and Prepare Instructors

The evaluation question for this impact was identified as

EQ #7 - What did we learn about the barriers and success for attracting and preparing new instructors in vacuum technology?

The data sources used to evaluate this question included

- Project team focus group
- Faculty interviews

EQ #7 – Attracting New Instructors from Industry

Over the five-year period of the DELIVER project, Normandale’s vacuum technology program recruited new instructors from both industry and academia (related physical science programs at Normandale). Prospects from industry were attracted to the application and troubleshooting aspects, while prospects from academia were attracted to the application of science concepts to industry.

The original idea was for instructors to be recruited from industry. Opinion among the project team has evolved on that approach based on experience. Existing faculty from the physical sciences have worked out better. They already know the learning management system, how to build course content, and teaching pedagogy and can more easily learn the technical applications needed by industry.

Interviews with the project team and with these recruited faculty yielded observations for both approaches. Some representative observations for both approaches are summarized in the table below.

From Industry	From Academia
<ul style="list-style-type: none">• <i>Industry can best teach VACT 2293 and 2297 since they are more applied courses.</i>• <i>Industry still needs to have an interest in teaching to be successful.</i>• <i>“The pay is low for the knowledge and effort required.”</i>• <i>“Industry instructors have a harder time breaking concepts down to simpler levels for students, then building them back up to the more complex applications.”</i>• <i>“In hindsight, onboarding a person from industry to teach a VACT class is a big undertaking and will probably be intimidating for most individuals from industry. They may come to the class with the expertise on the subject matter and probably comfort with executing the hands-on activities. However, if they have no prior experience in teaching there will be the following systems to learn: the maintaining the course in the learning</i>	<ul style="list-style-type: none">• <i>Academia can best teach the foundations and intro courses (VACT 1010 and VACT 1292) since they focus more on concepts.</i>• <i>“Would probably look to reach out to another engineering or science faculty before recruiting from industry.”</i>• <i>“Comparatively speaking it seemed like it was much easier for the individual who had several years of instructional experience to acquaint herself with the content and adjust to teaching a VACT course than it was for the individual who had more years of working in industry to learn how to teach.”</i>• <i>I think that we may be able to attract some traditional educators from engineering or science disciplines, specifically physical chemistry or material science, who may really enjoy teaching the VACT courses.</i>

<p><i>management system, classroom management, using the telepresence system effectively, using the grade reporting system and other administrative tasks.”</i></p> <ul style="list-style-type: none"> • <i>“Attracting individuals with a background using vacuum technology in industry to teach these classes will be extremely difficult.”</i> • <i>An instructor from industry has “street cred.”</i> • <i>Knowledge of vacuum technology applications is valuable.</i> 	
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Figure 38 - Recruiting Instructors from Industry versus Academia

Some key themes on this question that were uncovered in faculty interviews include:

- **Recruitment was relationship driven** – importance of program leadership and the trust and personal investment in the new instructors’ success.
 - *“...both Nancy and John were excellent in communicating the vision and a passion for the program when recruiting.”*
 - *“Nancy has been very organized and communicates well; Ruth and Nancy met several times over six months. Ruth provided all material; one of the easiest classes to learn to teach.”*
- **Auditing/observing the class ahead of teaching was a key contributor to success**
 - *“Auditing the class was a great preparation for a new instructor.”*
- **Embracing problem solving and troubleshooting skills are key**
 - *“An important quality as part of the instructional delivery for the instructor to embrace the problem solving aspects since this will be the foundational aspect of most of the student’s own work on current and future job assignments.”*
- **The project developed excellent resources shared with new instructors**
 - *“This was the most take it off the shelf and go class that I have ever taught”*
 - *“My first experience teaching VACT 1292 was only doable because I had access to excellent resources developed previously”*
- **Collaborative teaching** with new instructors

Some other recommendations from newly recruited faculty that Normandale should consider implementing (for both the vacuum technology program as well as other technology programs) include:

- From the perspective of program content, industry probably serves in the best role to confirm the value of the program when they (1) repeatedly hire students from the program, (2) recommend that their incumbent employees enroll in Normandale’s Vacuum Technology classes as a way to improve their skills working with vacuum systems, and (3) participate in an advisory role to provide the college with feedback with respect to the course content and offerings.
- A mentoring program to review and coach new instructors, review/critique their presentations, identify learning priorities, to help fill in the gaps would be helpful.
- The new instructor first and foremost must have intellectual curiosity and an interest in knowing about the subject. It is not as important to have a deep background in vacuum technology as it is to have a thorough grounding in the underlying physical and thermodynamic principles of gas

fluid dynamics; at that point a curious person with a manufacturing background can comprehend the technical issues associated with vacuum technology.

- Recommend summer workshop for new instructors to help learn the learning management system, virtual technology, and pedagogy.
- Recommend providing new instructors with grading rubrics.
- Every session should have a video recording of past classes for new instructors - with this any science instructor could be onboarded easily.

Key Findings – Attracting New Instructors

EQ #7 – What did we learn about the barriers and success for attracting and preparing new instructors in vacuum technology?

- Existing science and engineering faculty provided a better source for new instructors than industry
- Recruitment was relationship driven – importance of program leadership and the trust and personal investment in the new instructors' success.
- Auditing/observing the class ahead of teaching was a key contributor to success
- Embracing problem solving and troubleshooting skills are key
- The project developed excellent resources shared with new instructors
- Collaborative teaching with new instructors was a positive experience

Supplemental Award – Undergraduate Research Experience (URE)

Normandale Community College received supplemental funding for project *Distance Education and Learning In Vacuum Technology for Employment Readiness* (Project DELIVER; NSF DUE #1700624) in October 2020. This funding was to engage approximately 24 students enrolled in the vacuum technology, engineering, and physics programs at Normandale in undergraduate research experiences (UREs) over three semesters during 2021-2022.

The key evaluation questions developed for this supplement are:

- 1) What is the impact of the undergraduate research experience on the integration of knowledge related to
 - a. VACT 2293 learning objectives
 - b. Workplace technical skills
 - c. Understanding of vacuum technology equipment
 - d. Engineering design process
- 2) What is the impact of the undergraduate research experience on students' preparation for a career in vacuum technology?
 - a. Students are prepared for life-long learning, future personal, academic and/or professional pursuits, and their roles as members of various communities.
 - b. They will demonstrate the common attributes of top-quality engineers and technicians.
- 3) What is the impact of the undergraduate research experience on students' ability to communicate how the research project contributes to a sense of closure, accomplishment, purpose, and agency?

A detailed evaluation report for this supplement has been provided for this supplemental project activity². A summary of the key findings is provided in the table below.

Significant Impacts from URE Project
<ul style="list-style-type: none"> • Enhanced student learning for vacuum technology students <ul style="list-style-type: none"> ○ Specific examples include enhanced technical content, improved troubleshooting skills, multi-discipline applications and teamwork
<ul style="list-style-type: none"> • Real world application of technical content <ul style="list-style-type: none"> ○ Specific examples include real world experience and exposure to industry grade hardware
<ul style="list-style-type: none"> • Enhanced faculty professional development
<ul style="list-style-type: none"> • Improvement of Normandale’s vacuum technology curriculum and program by providing “hands-on” opportunities to distance learning students

Sustainability

The broad categories of sustainability of ATE Projects and Centers include the institutionalization of elements of the project, perpetuation of activities or relationships started under the grant, and continued availability of new products or activities.

Applying Welch’s Checklist for Assessing the Sustainability of ATE Projects and Centers (2013)³ provides a measure of this project’s sustainability. Figure 39 shows that NCC’s Project Deliver rates positively on 65% of factors predicting sustainability, and only 9% for negative factors. Both compare favorably to a benchmark assessment of over 200 ATE projects and centers from 2010.⁴

² “Shaping the Future of Vacuum Technology Education – 2020- 2021 Virtual Workshops”; Normandale Community College NSF ATE Award #1700624, prepared by Outcomes Consulting Services, June, 2021

³ “A Checklist for Assessing the Sustainability of Advanced Technological Education (ATE) Projects and Centers”; NSF Targeted Research Grant # 1132099, Wayne W. Welch, PI

⁴ “A Checklist for Assessing the Sustainability of Advanced Technological Education (ATE) Projects and Centers”; NSF Targeted Research Grant # 1132099, Wayne W. Welch, PI

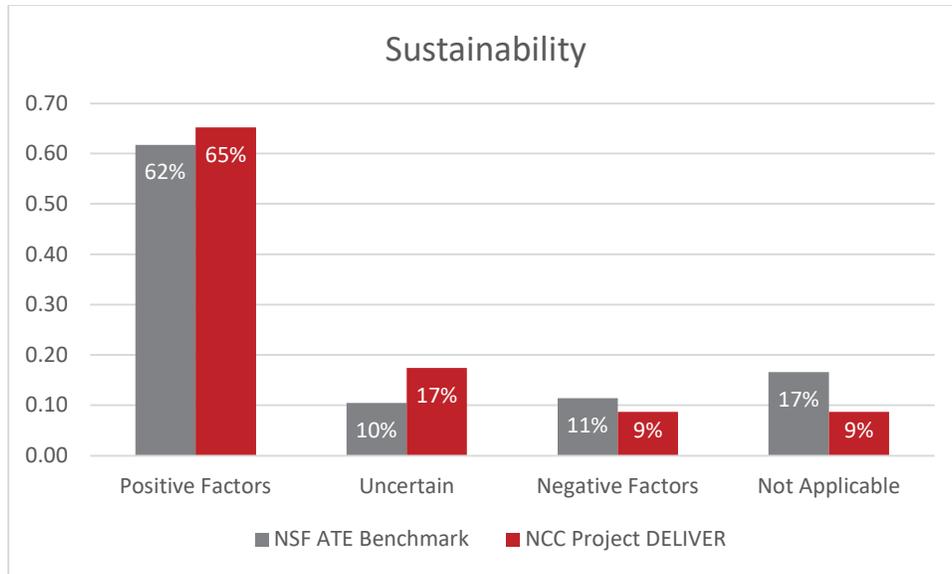


Figure 39 - Sustainability Benchmarks

Some opportunities that have been identified that could improve the project’s sustainability going forward include:

- Evaluating the retention rate between Foundations in Vacuum Science (VACT 1010) and Introduction to Vacuum Technology (VACT 1292) and developing strategies for addressing the issues found.
- Continue to focus on meeting the needs of incumbent workers (see NSF ATE award #2202126 “Support Strategies to Upskill/Reskill Students Who are Incumbent Workers”)
- Incorporate lessons learned into NSF ATE award #2000454 to Erie Community College “Developing an E-Book and Other Interactive Instructional Materials for Technician Education in Vacuum Technology”
- Institutionalize the measurement of the quality of industry partnerships
- Expand the utilization of the VET’s in the program curriculum
- Explore the incorporation of research experiences into the program’s curriculum
- Utilize the End-of-Semester survey data from the project to improve the program
- Explore internship or apprenticeship programs with industry (see quote below from an industry partner)

“I believe Normandale should consider partnering with local companies in the Twin Cities metropolitan area to develop a vacuum maintenance/process technician apprenticeship program. Local companies are not finding enough hires currently and will need to be more proactive in training up new hires or working with local education institutions to outsource academic training in maintenance of vacuum systems. Too often, industry asks someone else to do the heavy-lifting for them. Industry should take a more active role in worker training, the same way manufacturing companies in Germany do.”(NCC Advisory Board Member)

Appendices

Survey Data files

- VACT 1010 End of Semester (EoS) Student Survey
 - *“VACT 1010 EoS Survey Results Master File for Submittal”*
- VACT 1292/2293/2297 End of Semester (EoS) Student Survey – sorted by instructor
 - *“VACT 1292/2293/2297 EoS Survey Results Master File for Submittal”*
- URE VACT 1194 Student Survey
 - *“VACT 1194 Student Survey Results Master File for Submittal”*
- VET Survey
 - *“HVETRVET Trainers in VACT Courses Master”*
- Industry Survey
 - *“SVC Survey Results June 2021”*

Supplemental reports

- “Shaping the Future of Vacuum Technology Education – 2020- 2021 Virtual Workshops”; Normandale Community College NSF ATE Award #1700624, prepared by Outcomes Consulting Services, June, 2021 (<https://www.normandale.edu/departments/stem/vacuum-and-thin-film-technology/shaping-the-future-of-vacuum-technology-education>)
- “External Evaluation Report – Undergraduate Research Experience (URE)”; Normandale Community College NSF ATE Award #1700624, prepared by Outcomes Consulting Services, July, 2022