

# Collaborative Course Delivery as a Strategy to Sustain Niche Technology Programs

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## Abstract

Vacuum technology is critical to research and advanced manufacturing industries such as semiconductor and nanotechnology. To meet rising industry demand for qualified technicians working with vacuum equipment, SUNY Erie Community College (SUNY Erie) considered developing a Vacuum Technology program or adding vacuum courses to existing Electrical Engineering Technology and Nanotechnology programs. However, vacuum technology is a highly specialized area. It is costly to develop, deliver, and sustain technical programs (curriculum, equipment, instructional talent, numbers of students available locally) at community and technical colleges. Therefore, finding a way to share programmatic resources became essential. The partnership with Normandale Community College's (Normandale CC) existing Vacuum Technology program was developed as a result.

Normandale CC offers a curriculum in Vacuum Technology using video conferencing (telepresence classroom) to teach classes synchronously to distance sites. This distance education mode was developed as part of a NSF-ATE funded project and incorporates a hands-on component utilizing a Vacuum Equipment Trainer (VET) system shipped to the remote locations. This delivery mode addresses equipment expense, faculty expertise and student demographics issues that are common to seated courses. For example, student demographics include non-traditional students working full-time and not able to attend seated courses. This delivery mode also overcomes the limitations of online course delivery by adding "live" in-class interactions and hands-on experiences.

This faculty paper discusses the logistics of a classroom partnership across institutions during Spring 2018: negotiating differences in time zones, course schedules, and program curriculum; shared online learning management systems; student registration logistics for a class offered from another institution in a different state; and faculty compensation. It also addresses the process of developing and negotiating a contract that governs the partnership. In this case, funding from NSF reduced the financial burdens and risks for both institutions. The paper reports student and faculty assessments of the partnership, including problems encountered during course delivery, and potential solutions. Finally, the importance of networking opportunities for community college technical programs' survival and next steps in the partnership development are discussed.

## 1.0 Introduction

The rapid development of manufacturing facilities working with matter manipulations on the nanometer scale is remarkably similar to the Third Industrial Revolution (computer revolution) in the twentieth century. One of the key components of nanometer scale fabrication and

characterization is vacuum technology since numerous instruments require sub-atmospheric pressure to run processes and/or characterize products. Vacuum and thin film technologies are critical to advanced manufacturing industries that produce virtually all electronic devices, including computer microprocessors and memory chips, flat panel displays, and communications devices. Within these industries, vacuum technicians are responsible for maintaining and troubleshooting complex vacuum systems. To succeed in their jobs, vacuum technicians apply higher-order thinking skills, especially in math and science, along with a blend of problem-solving and hands-on skills<sup>1</sup>.

As vacuum systems have become more complicated, a comprehensive education program is needed to convey the complex concepts in vacuum science. However, few formal vacuum technology education programs exist in the U.S. Vacuum-reliant industries are clustered in a few states (Arizona, Minnesota, New York, California, Oregon, Texas), and there are a finite number of vacuum technician positions within a business: typically, two to ten, but 50-100 in very large foundries. The demand for vacuum technicians in many regions is not great enough to sustain a formal program of study. However, the national need for vacuum technicians is increasing, especially in areas such as green technology like solar cell and light emitting diode (LED) fabrication. In addition, the ongoing retirement of experienced, skilled workers and the recognition of the lengthy time needed for an individual to develop this technical skill set contributes to increased hiring needs<sup>1</sup>.

This paper will:

- Introduce Vacuum Technology curriculum development efforts in the Western NY area;
- Describe the motivations of SUNY Erie in pursuing partnerships in developing the curriculum;
- Discuss the logistics and policies required to form a partnership across institutions and state educational systems to teach Vacuum Technology courses;
- Describe the successful teaching modalities for vacuum technology courses; and,
- Analyze the results of the partnership and discuss future plans for the partnership.

## **2.0 Motivation for Developing a Partnership to Teach Vacuum Technology Courses**

In 2014, SUNY Erie developed a two-year program in Nanotechnology and added courses in semiconductor fabrication to the existing two-year AAS program in Electrical Engineering Technology (EET). A very rudimentary introduction to Vacuum Technology was included in both the Nanotechnology program and semiconductor fabrication courses for the EET program. The vacuum-related portion of the curriculum was developed with input from the Nanotechnology program at Pennsylvania State University. However, faculty at SUNY Erie realized that more extensive coursework in Vacuum Technology would enhance the employability of students from both programs. Industries around the country require their employees to have a much broader skillset in Vacuum Technology (with an emphasis on a hands-on component) than was currently embedded in either the Nanotechnology or EET programs. Therefore, SUNY Erie had to consider how to expand their curriculum in Vacuum Technology. However, faculty were confronted with several challenges.

Vacuum Technology can be considered a niche technical field within the broader discipline of engineering. A niche program can be characterized as: having a high-cost barrier to entry in developing curriculum and in acquiring and maintaining lab equipment; having a scarcity of qualified teaching faculty with the necessary technical expertise; and, attracting and retaining smaller student populations to the field. Below we discuss in more detail the challenges associated with these characteristics.

*2.1 Curriculum development.* One reason Vacuum Technology is a niche program is because it combines concepts from algebra, chemistry, and physics. Achieving the correct blend of topics and course sequencing requires faculty and curriculum developers to have deep industry expertise and an understanding of two-year college curricula. Vacuum technology education must also include hands-on learning. In industry, vacuum technicians work with multi-million-dollar equipment; learning on the job can be costly. However, two-year colleges have limited access to the funding necessary to develop courses or programs in such capital-intensive fields as Vacuum Technology (and Nanotechnology, Semiconductor / MEMs / Photovoltaic fabrication). Also, it is expensive for two-year colleges to buy off-the-shelf equipment for hands-on learning, and it is challenging and expensive to build equipment at each institution.

*2.2 Qualified faculty.* Most science, engineering, and technology departments at two-year institutions are small – usually two to five faculty members who teach multiple classes in the same field or multiple sections of the same class. This staffing model typically does not support a breadth of expertise across many technical fields. With vacuum technology being a niche field, the probability of having existing faculty and staff with experience in the vacuum technology field is extremely low. Creating new faculty positions to attract experts in vacuum technology, or any niche field, is nearly impossible due to the financial limitations of these institutions.

*2.3 Student populations.* Even though advanced manufacturing industries need a steady supply of technicians capable of working with vacuum systems, it is very difficult to attract a sufficient population of students to regularly enroll in vacuum technology programs. Most students from two-year technical programs find mathematics, physics and chemistry courses very difficult, which deters potential students from seeking an AAS degree or even a certificate. Furthermore, the local demand for the technicians who are proficient in working with vacuum systems is limited even though nation-wide demand is high. This results in a small number of students enrolling in vacuum technology courses, which makes it difficult for two-year institutions to justify the expense of offering the courses and program.

One solution to these challenges is to share programmatic resources between two-year and four-year institutions. The next section describes how SUNY Erie established a partnership with Normandale CC to supplement the Vacuum Technology curriculum and to offer SUNY Erie students the opportunity for hands-on learning.

### **3.0 Finding a Partner in Vacuum Technology Education**

The activities described in this paper would not have been possible without the funding and opportunities provided by the National Science Foundation's (NSF) Advanced Technological Education (ATE) program. For twenty-five years, the ATE program has funded projects at two-year institutions that focus on educating technicians for employment in high-technology fields. The ATE program supports partnerships between academic institutions and industry to promote improvement in the education of science and engineering technicians, including curriculum development and professional development<sup>2,3</sup>. The program also provides opportunities for Principle Investigators (PIs) to share their progress and network, namely at the ATE PI Conference, usually held in the Fall, and the HI-TEC (High Impact Technology Exchange Conference), usually held in the Summer.

The 2017 HI-TEC provided an opportunity for SUNY Erie faculty and Normandale CC faculty to meet during the Micro- Nano- Technology (MNT) Special Interest Group. Through follow-up conversations, faculty from SUNY Erie and Normandale CC explored how a partnership could meet the unique needs of both institutions. Below we briefly describe the activities at Normandale CC that made them a potential partner for SUNY Erie.

Since 1998, Normandale CC has offered an Associate of Applied Science (AAS) degree and two certificates in Vacuum and Thin Film Technology, which was developed to meet the needs of local industries that needed a pipeline of vacuum technicians. However, once a critical mass of vacuum technicians completed the program, class sizes became smaller, putting the Vacuum and Thin Film Technology program at risk for closing due to low enrollment. At the same time, the nationwide demand for qualified vacuum technicians was increasing. Large fabrication facilities employing from 20 to 100 (or more) vacuum technicians are clustered in Arizona, Minnesota, New York, California, Oregon, and Texas. However, small- and mid-sized manufacturers that rely on vacuum systems are found throughout the country. In 2014, Normandale CC was awarded a grant from the ATE program (Project ReVAMP, DUE #1400408) to explore ways to sustain the Vacuum and Thin Film technology program and meet the national demand for vacuum technicians.

The three main Project ReVAMP activities included: 1) updating the vacuum technology curriculum and developing a Vacuum Equipment Trainer (VET) system to support hands-on learning; 2) delivering vacuum technology courses via telepresence; and, 3) partnering with industry or academic institutions to achieve a threshold of sustainable enrollments at Normandale CC while providing national access to vacuum technology education.

The target audiences for Project ReVAMP were higher education institutions with new students entering the field and industry partners with an existing workforce. The target financial and administrative model was contingent on partner institutions registering their students or employees in Normandale CC courses, which would result in an increase in enrollments. The target teaching and learning model included using the VET system, which was shipped to participants at off-site locations, so they could participate in hands-on learning while linked in

real-time via telepresence to a Normandale CC instructor. Table 1 compares teaching and learning modes and how telepresence specifically supports vacuum technology education. Figure 1 shows a telepresence classroom.

*Table 1: Comparing Modes of Delivery for Teaching and Learning Technical Topics*

	<b>Seated Class</b>	<b>Online Class</b>	<b>Telepresence Class</b>
<b>Advantages</b>	Access to the instructor, personal interactions, hands-on activities	Asynchronous delivery accommodates non-traditional students, differently-abled learners; eliminates cost of space	Synchronous faculty / student interaction; hands-on activities on-site and off-site; not limited by geography
<b>Disadvantages</b>	Cost of space, travel time; geographic limitations	Reduced faculty / student interaction; no effective way to introduce hands-on activities	Cost of space (or repurposing space); administrative cost to align institution policies and practices
<b>Impact</b>	Personal interactions with instructor but excludes students beyond a reasonable commuting range	Increased access to learning opportunities but dependent on student motivation; some topics not effectively conveyed online	Increased access to learning opportunities; real-time faculty / student facilitates teaching complicated technical topics; hands-on learning possible

*Figure 1 Telepresence classroom at Normandale Community College showing VET systems being used onsite and off-site*



In 2017, Normandale CC received a second ATE grant (Project DELIVER, DUE #1700624) to complete the curriculum development and revision process, so that students and incumbent workers can receive a certificate in Vacuum Technology after completing a four-course sequence. This project expands pathways into the vacuum technology field and provides support to increase the number of partnerships between Normandale Community College, industry, academic institutions, and professional societies.

A whitepaper written at the conclusion of Project ReVAMP describes the lessons learned from developing partnerships with industry and higher education institutions<sup>1</sup>. To date, 154 unique participants were enrolled and educated in vacuum technology courses. Off-site partners from around the country include:

- Six businesses in industries that rely on vacuum technology systems;
- Three academic institutions (one 4-year university; two 2-year colleges);
- One U.S. national laboratory.

When faculty from SUNY Erie and Normandale CC met at HI-TEC in 2017, SUNY Erie was exploring how to expand its offering in Vacuum Technology and Normandale CC was exploring how to engage with more partners to take vacuum technology courses via the telepresence delivery model. The rest of this paper discusses the practices and policies that had to be resolved in order to establish a partnership between two academic institutions. Then we describe the experience and lessons learned in jointly offering *Introduction to Vacuum Technology* telepresence course at SUNY Erie in Spring 2018.

#### **4.0 Forming a Partnership between Academic Institutions**

Even though SUNY Erie and Normandale CC wanted to establish a partnership, there were many logistical and legal details to resolve before *Introduction to Vacuum Technology* could be offered. The entire process took five months. For comparison, the first partnership Normandale CC established with a four-year academic institution took two years to finalize. However, once industry partners decided to enroll a cohort of employees in a Normandale CC class, the enrollment process could be completed within two to four weeks before the start of class.

As a result of establishing partnerships with other academic institutions, Normandale CC already had a model document, called the Joint Powers Agreement (JPA). This legal document addressed the transactional details between colleges, including responsibilities of each institution for course logistics and instructor compensation; these are discussed in more detail below. Both Normandale CC and SUNY Erie had to negotiate the details of these items and then sign the JPA. In addition, a Memorandum of Understanding (MOU) between the faculty federation union and SUNY Erie had to be negotiated and signed to allow a one-time union contract modification in the faculty compensation for the joint course.

One of the biggest hurdles in establishing a partnership to jointly offer the *Introduction to Vacuum Technology* course at SUNY Erie was getting buy-in from the administration and faculty union. This challenge was resolved through the monumental effort of the senior faculty member in the EET department at SUNY Erie, who championed the benefits of the joint offering. Below we discuss how issues were resolved in order to establish a partnership between SUNY Erie and Normandale CC.

*4.1 Union contracts.* According to the union contract between the faculty federation and SUNY Erie, all SUNY Erie courses must be taught by the SUNY Erie college's faculty. This clause in the contract was introduced to protect faculty members' instructional load from being outsourced in the administration's effort to reduce costs. However, in niche fields such as Vacuum Technology, the future depends on offering courses jointly with other institutions for the reasons detailed in section 2.0. For SUNY Erie and Normandale CC to proceed, a special temporary dispensation had to be negotiated with the union to allow vacuum course to be jointly taught by Normandale CC and SUNY Erie faculty. A new vacuum course, identical to the Normandale CC's course, was created in the SUNY Erie course catalog and approved at the SUNY Erie. A full-time faculty member was assigned to the course at the SUNY Erie site to staff the telepresence room.

*4.2 Instructor compensation.* Faculty time is one of the largest costs associated with teaching the vacuum technology courses at Normandale CC. The motivation for scaling up the number of off-site partners and enrolled students is to cover the costs of Normandale CC instructor time. Having a faculty member staff an off-site class (at SUNY Erie) is expensive and redundant and is a disincentive to forming a partnership.

The activities that need to be managed at an off-site classroom include: classroom management; proctoring exams; interfacing with IT staff; and, being responsible for the VET system

(receiving, shipping, assembly, preparation, monitoring class demonstrations and use, storage, troubleshooting and repair). Ideally, these responsibilities would be split between a non-faculty staff member (technical assistant, lab assistant or student worker), who would manage activities at an offsite classroom, and technical and/or IT staff, who would manage the trainer and remote access logistics. Any such accommodation would need to take into account faculty and union contracts, scheduling, and student competency.

According to the SUNY Erie union contract, only full-time or adjunct faculty can be assigned to any course as an instructor. Therefore, in Spring 2018, one full-time paid instructor was assigned to teach the course at the remote site and one IT technician was paid to provide support with the vacuum trainer and connectivity issues. This model worked for Spring 2018 because a special agreement was reached with the union and because additional grant funding at Normandale CC was in place to fund these positions at SUNY Erie. To make the joint offering of Vacuum Technology courses financially sustainable or scalable in the future, SUNY Erie will have to negotiate the possibility of non-faculty members staffing the telepresence classroom.

For comparison, faculty union contracts and rigid staffing assignments are not a factor in the partnerships that Normandale CC has formed with industry. The roles associated with ensuring a telepresence course runs smoothly at an off-site industry location are: Human Resources (proctoring exams, managing registration, and LMS access); Equipment Manager (managing the VET shipping and storage, ensuring employee attendance); and IT (establishing and supporting telepresence).

*4.3 Student registration.* The next issue to resolve was which institution should collect SUNY Erie student tuition in order to pay the Normandale CC instructor. Ultimately, SUNY Erie retained their student registration fees for the course. NSF funding supported the cost of the Normandale CC instructor, the cost of SUNY Erie staff time, and the cost of shipping the VET system to and from SUNY Erie. Without funding from NSF, this academic partnership would not have been possible. With industry partnerships, NSF funding supports the costs of shipping the VET system and the time of Normandale CC staff to manage the registration process. In some Normandale CC vacuum classes, industry employee enrollments are steadily growing so that they fully fund the Normandale CC instructor's time.

*4.4 Learning Management System (LMS).* A new angle to the partnership with SUNY Erie was that the institution used a different LMS than Normandale CC. This was not the case with Normandale CC's first academic partnership. Course materials could not be shared between the systems, but SUNY Erie students needed access to the Normandale CC LMS to take the course. A solution was reached by the Normandale CC IT department, who created semester-long guest accounts in the LMS for the SUNY Erie students.

*4.5 Time zones.* In Spring 2018, there were three institutions (two industry partners plus SUNY Erie) with students enrolled in *Introduction to Vacuum Technology*. The course had to be scheduled over three time zones to accommodate these institutions. This was not a major



undertaking, but effort had to be made to reconcile scheduling constraints from three different sites including the host institution.

*4.6 College schedules.* The timing of student enrollment also posed a challenge. Spring semester at Normandale CC started one week earlier than that at SUNY Erie. Therefore, students at the remote site had to register earlier than they normally would, and they had to start attending the vacuum course one week prior the start of the semester at SUNY Erie. In addition to this, the scheduled spring recesses at both colleges did not match, so students at SUNY Erie had to be aware that they would be attending the vacuum class during their spring recess. Attendance during spring recess did not drop significantly. However, the mismatch in schedules at the start of the semester was difficult for SUNY Erie students. During first week of classes at SUNY Erie, which was the second week of classes at the host site, several additional SUNY Erie students wanted to enroll in the vacuum course during add/drop week. They were allowed to register in the course (due to the SUNY Erie's policy during add/drop week), but they had to catch up with the material presented during first two class sessions and corresponding homework assignments. A cohort of workers from an industry partner was also enrolled in Spring 2018. They did not have the same challenges with the enrollment timing since they were registered during the add/drop week at the host institution.

*4.7 Program curriculum.* Even though SUNY Erie incorporated one course from the Normandale CC Vacuum Technology program into its EET program, the course sequencing and the level at which students engaged with the curriculum posed a challenge. At Normandale CC, *Introduction to Vacuum Technology* is the first course in the sequence of three vacuum courses. Ideally, EET students at SUNY Erie should take this course in the second or third semester of their program, followed by another one or two vacuum courses during their fourth semester if they plan to work in the vacuum industry or to enhance their skillset in this area. However, the only way vacuum course(s) can currently be incorporated into the EET program is as technical elective course(s) taken during the fourth semester. A result of this mis-alignment in sequencing between institutions was that some parts of the *Introduction to Vacuum Technology* course were too rudimentary for fourth semester students. As a result, the EET department has since made revisions to the program that allow for one technical elective course during the third semester. This will allow students to take the introductory vacuum course during third semester and one or two advanced vacuum courses during the fourth semester. This will also allow for the creation of a stackable certificate in Vacuum Technology within a two-year EET degree.

#### 4.8 Vacuum Equipment Trainer (VET) system.

The VET system is a critical part of the *Introduction to Vacuum Technology* course. In the workplace, expensive vacuum systems are housed in "clean" rooms; vacuum technicians must wear sterile scrubs and be vigilant about contamination. It is important that students gain hands-on experience with these systems before entering such a high-stakes environment. With a grant from the Minnesota Leveraged Equipment state matching funds program, Normandale CC built four Rough Vacuum Equipment Trainer (RVET) systems to use with *Introduction to Vacuum Technology* (see Figure 2). RVETs are shipped to partners, so off-site students can have the same experience as Normandale CC students. Part of establishing a partnership is working out the financial details for shipping and insurance. Other details to resolve include funding staff to receive the RVET system, then coordinate its assembly before the course begins, perform maintenance and trouble-shooting during the course, and then disassemble and return the system. At SUNY Erie, managing the RVET logistics required working closely with the accounting department. It also required technical staffing support from within the EET department.



**Figure 2 Rough Vacuum Equipment Trainer System**

*4.9 Telepresence facility.* Telepresence, or teleconferencing, systems include an audio / video connection, often with multiple screens, delivered with no delay in the signal. This synchronous-at-a-distance connection between Normandale CC and offsite partners is key to delivering vacuum technology education. Since Normandale CC first received funding from NSF, the cost of the components for a telepresence system (cameras, microphones, screens, connection software) have steadily gone down, while conferencing services have expanded beyond Cisco to include, for example, Blue Jeans, Zoom, or Skype.

Not having a synchronous telepresence connection would present a barrier for starting a partnership. However, the EET department at SUNY Erie had unimpeded access to the conference room with reasonable teleconferencing capabilities. There is a large-screen monitor (with back-mounted computer) with webcam and microphone system. Even though the system is not very sophisticated, it is sufficient for participating in a joint course via telepresence. The conference room can seat a maximum of 14 students and connects to a room that can house the VET system between class sessions. The experience of SUNY Erie demonstrates that no special expenditures are needed to accommodate the telepresence model of course delivery at a remote site as long as an average teleconferencing space is available.

*4.10 Recommendations.* The National Science Foundation regularly encourages institutions to form partnerships in its requests for proposals. Based on the experience of SUNY Erie and Normandale CC, we have learned that, in fact, creating a partnership across two academic institutions, educational systems, and state boundaries is a remarkable undertaking and is not easy by any means. There are several recommendations for institutions that would like to establish the level of partnership that we accomplished:

- When establishing an academic partnership, enlist the support of a faculty member (or team of faculty/staff) from the department that would host the course and who has a degree of seniority and is familiar with local policies and politics.
- Establish a team comprised of representatives from: the business office (contract negotiations and accounting); human resources (assignment adjustments); IT support; and, admissions / registration.
- Discuss LMS systems compatibility early in the process.
- Identify the facility for running the telepresence course early in the process.

## 5.0 Delivering Technical Content and Hands-on Learning via Telepresence: Lessons Learned

As noted above, the cost of telepresence technology continues to diminish such that this mode of teaching and learning is becoming viable for institutions with tight budgets. Table 2 compares the features of telepresence classrooms at SUNY Erie and Normandale CC with the minimum technology requirements. These requirements were developed by Normandale CC through their experience with various partners.

*Table 2 A Comparison of Telepresence Requirements & Implementations*

	<b>Minimum Telepresence Requirements</b>	<b>Remote Telepresence Classroom (SUNY Erie)</b>	<b>Host Telepresence Classroom (Normandale CC)</b>
<b>Display Screens</b>	Two monitors, one to view the instructor and classroom and one to show content	One 70" wall-mounted monitor with the computer, camera and speakers	Three large high definition monitors, one of which is a touch screen
<b>Cameras / Microphones</b>	One camera at the remote site to provide a view of the students and the off-site vacuum trainer to the instructor at the host site	Camera, speakers, microphones embedded in the monitor	Three high definition cameras, two in front of class, one in back provides detailed view of equipment; High-performance microphones and speakers, responsive to voices around the room
<b>Room Size</b>	Pick a "right-sized" room that accommodates the number of offsite students and vacuum trainer system and that has movable furniture	Teleconference room, not a classroom	Lab space with movable furniture; System controlled by a touch pad at the instructor's location.
<b>VET systems</b>	4-6 students per system	3-4 students per system	4-5 students per system

While some of the arrangements at SUNY Erie did not meet the minimum requirements, IT staff and EET faculty found solutions to enable the telepresence connection to be used effectively.

- For the one large monitor, they arranged the split image on the BlueJeans teleconferencing system that allowed SUNY Erie to see the host classroom, instructor, and slides at the same time. The large size of the remote classroom screen compensated for not having two screens.
- Since the teleconference room was used mainly for administrative meetings, there was limited space for the VET system, which could only accommodate up to three students

working on a trainer simultaneously. This potential drawback yielded a valuable lesson: even though Normandale CC recommended 4-6 students per trainer, SUNY Erie found out that three, or maybe four, students per trainer is a better ratio.

In addition to resolving the technology and room design details, the following lessons were learned regarding staffing and cost for using telepresence:

- IT or technical staff should be available to troubleshoot issues during initial set up and as they arise during class. This step could be fulfilled by the faculty assigned to the course as well.
- There can be some administrative overhead in scheduling the facility that has the telepresence technology.
- There is a time cost in the incidentals of making the telepresence system work for each class period, which might require a faculty member or manager.

With the telepresence details resolved, the typical *Introduction to Vacuum Technology* class at SUNY Erie took place as follows:

- The duration of the weekly course was about two hours.
- The first five minutes of class time was dedicated to organizational topics.
- The lecture portion would take usually one to one-and-a-half hours depending on the topic. During the lecture portion, hands-on calculations and various engaging activities were performed.
- The last portion of the class (30 minutes to one hour) was dedicated to the hands-on activities where the instructor at the host site would demonstrate the procedure, which was then repeated at the remote sites.
- Several times a semester, the last portion of the class was replaced with an online, timed, and proctored test. The remote-site supporting staff proctored the tests, but all grading of tests (and homework assignments) was done by the host institutions' instructor.
- One class was replaced by the tour of a local vacuum industry facility. Students had to complete homework assignment based on the information from the tour instead of regular homework assignment for that week.

Based on the experience of jointly running the *Introduction to Vacuum Technology* course during Spring 2018, SUNY Erie faculty and students had the following feedback:

- Overall, the course design strategy was successful.
- The LMS used for this course (D2L) was helpful and straightforward. It supported course materials, quizzes and tests fairly well. The only challenging step in using the D2L system was related to using this system for testing: students had problems when typing lengthy formulas required during tests within the given time-frame.
- Students were able to interact with the instructor at the host site whenever they had questions. Time for site-to-site interactions was also factored into the course.
- The telepresence system worked well. Students at SUNY Erie were able to get good quality video and audio input from the host site. Students were also able to see and hear

the feedback and discussions from other remote sites. The instructor at the host site was able to get good video and audio feedback from SUNY Erie as well.

- The VET systems were absolutely indispensable in getting hands-on experience. The feedback from students indicated that no more than three students should be assigned to one VET. Otherwise students are not able to gain enough valuable hands-on experience.
- Study guides for each lesson were very helpful in keeping students focused and organized.

## **6.0 Analysis of Partnership Results and Next Steps**

Overall, offering the *Introduction to Vacuum Technology* course via telepresence with a VET system in the classroom was a success. This model allowed SUNY Erie to utilize faculty expertise at Normandale CC, which faculty at the EET department of SUNY Erie did not possess.

Activities with the VET systems incorporated active learning into the curriculum. Faculty at SUNY Erie also had access to the Rough Vacuum Equipment Trainer (RVET) system over a semester to understand its design, operation, maintenance and troubleshooting issues in addition to providing students with the hands-on experience. Since the EET department is planning to expand its vacuum technology course offerings, we were interested in designing our own vacuum trainer. The experience with the RVET system used in this course gave SUNY Erie valuable input. The SUNY Erie faculty still plan to participate in joint course offerings with Normandale CC in the future, especially when offering advanced vacuum courses. However, vacuum technology training is incorporated in the EET and Nanotechnology courses; having a robust vacuum training systems is a must.

Finally, the live interaction with the instructor at the host site during class was extremely valuable. It created the “feel” of a real classroom. Plus, utilizing LMS with all the course materials allowed students to read some of the materials beforehand and practice the “flipped” classroom model<sup>4</sup>.

As part of the evaluation of the joint course in Spring 2018, students and faculty at SUNY Erie made suggestions that are being considered by the faculty at Normandale CC:

- The number of students per vacuum trainer ratio should not exceed three to four students per one vacuum trainer to ensure that all students have adequate hands-on experience.
- Next time any of the joint vacuum courses are offered, the logistics of cross-registering students in two colleges should be streamlined. It worked fairly well, but there were challenges in registering students within the first two weeks and setting up their accounts on the LMS system.
- Some of the more basic material (powers of ten, gas laws, pressure conversions, etc.) should be outsourced into a separate online course, which would be optional for students based on their preparation level.

Going forward, the EET department at SUNY Erie is planning to continue working in partnership with Normandale CC on offering several vacuum courses. The EET department is planning to offer vacuum courses within the Vacuum Technology certificate either as seated courses (if the number of registered students is seven or larger) or as joint courses via telepresence if the number of students is less than seven. SUNY Erie is also working on building the Rough Vacuum Equipment Trainer system as a means to reduce the cost of running a joint telepresence course. The EET department also built several high vacuum trainers similar to the High Vacuum Equipment Trainer (HVET) system from Normandale CC for the same purpose for advanced vacuum courses. The EET department is also planning on introducing additional, more advanced vacuum courses into the EET curriculum as well as packaging them into a stackable Vacuum Technology certificate. Appropriate changes in the structure of the EET program were already implemented and will be in effect starting Fall 2019.

One of the biggest challenges going forward is to make the partnership sustainable at Normandale CC and SUNY Erie after grant funding is not available anymore. For its part, Normandale CC will continue its partnership with SUNY Erie but will also continue to pursue partnerships with industry because there are significantly fewer processes to resolve, fewer policies to align or accommodate, and fewer subsidies needed. The lesson learned for Normandale CC is that few policies and processes align equally at academic institutions. At SUNY Erie, the EET department needs to develop permanent solutions for improving logistics for a distance partnership course delivery arrangements, such as: approving course curriculums that are aligned to partners'; updating program(s) if needed to incorporate new courses; course marketing; and, compensating faculty and administrative staff for new roles which support the partnership agreement. These solutions should help to keep partnerships viable even after NSF-ATE grant funding ends.

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