Developing Industry and Academic Partnerships to Deliver Vacuum Technology Education via Telepresence

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for
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A. Introduction

The goal of this document is *to report on the experience of establishing partnerships to deliver vacuum technology education courses via telepresence technology*. The courses were developed and delivered by Normandale Community College (Bloomington, MN) to remote sites at post-secondary institutions and vacuum-reliant industries in the U.S.

This work is funded by the National Science Foundation's Advanced Technological Education (ATE) program through Project ReVAMP (Revising Vacuum technology, an Advanced Manufacturing Program; DUE #1400408). The project objectives are to:

1. Revise two existing courses that are part of the Vacuum Technology program at Normandale. This includes adding or updating content as well as more strategically designing the online content posted in the learning management system (LMS) to encourage active learning.
2. Develop and build vacuum trainer systems that can be used in class for hands-on learning.
3. Deliver the courses to industry and post-secondary institutions using telepresence technology.

In order to achieve Objective 3, Project ReVAMP staff members first had to find institutions willing to have employees or students attend the vacuum technology courses. Then staff had to formalize organizational relationships between Normandale and these institutions by establishing workflow processes (e.g., schedule courses; enroll students; set up and support technology platforms) and by creating policies (e.g., administer course, grant credit).

Given the effort required to establish organizational relationships, project staff realized in hindsight that these activities should have been delineated in a fourth objective. The larger purpose for establishing institutional relationships was to test the scalability of the model for delivering education using telepresence and to explore the feasibility of sustaining the Vacuum Technology program at Normandale by increasing the number of enrolled students through the use of telepresence technology. This report documents the outcomes of this work.

Project ReVAMP is concluding its final year. In Fall 2017, staff members will begin working on Project DELIVER (Distance Education and Learning in Vacuum technology for Employment Readiness; DUE #1700624), which will build on the organizational work that was accomplished over the past three years of ReVAMP. This transition period presents an opportunity to gather and reflect on lessons learned, especially in the area of establishing partnerships. After describing our methodology, the report outlines the challenges facing vacuum technology education nationally and at Normandale, which directly influenced the design of ReVAMP and DELIVER and how staff members pursue partnerships. Then we list topics that emerged from a content analysis and summaries of lessons or observations associated with each topic. Finally, we provide recommendations about next steps for the work that will be carried forward in Project DELIVER.

The audiences for this report are: Project ReVAMP and DELIVER staff members; Normandale faculty and administrators; faculty, administrators, and managers at potential partner sites; the National Science Foundation; and, NSF projects or other organizations interested in scaling the delivery of STEM technical education at a distance.

A note on language

ReVAMP staff members have consistently used the word "partnership" to describe the organizational relationships they have pursued with businesses and post-secondary institutions. In some cases, this may not be the most accurate term. At the beginning of ReVAMP, "partnership" was a useful catchall that provided a conversational starting point. Based on experience, partnership has come to mean a willingness to accept shared risk to solve a shared need. For this report, we use "organizational relationship" and "partnership" interchangeably.

As partnerships were established, ReVAMP staff used words like "remote" and "off-site" to describe students or employees who attended class via telepresence. Students at Normandale were referred to as "local" or "onsite." Again, these terms are not entirely accurate because the telepresence technology makes classroom interactions immediate and dissolves distance.

B. Methodology

Data in this report was gathered through informal conversations (captured as field notes) or written personal observations from people in industry and higher education, who observed or facilitated the course *Intro to Vacuum Technology* (VACT 1292) from Spring 2015 to Spring 2017. Providing a brief summary and analysis of this data is not considered research; as such, no IRB review was required or sought. However, individuals' statements have been anonymized and are reported in aggregate.

To analyze the textual data in its loosely narrative form, we adopted a content analysis-lite method and used the process of emergent coding to identify themes across narratives. Even though the narratives reported experiences that were years apart and situated in different contexts, many common themes emerged. We think this is positive because the lessons learned could be broadly applicable and because these themes could provide a foundation for further study.

C. The State of Vacuum Technology Education

Vacuum and thin film technologies are critical to advanced manufacturing industries that produce virtually all the electronic devices that we use 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 hands-on skills.

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 (2-10 typically and up to 100 – 500 in very large foundries) within a business. 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 not decreasing. In fact, vacuum-reliant industries and businesses are increasing, especially in areas such as green technology like solar cell and light emitting diode (LED) fabrication. In addition,

the on-going retirement of experienced, skilled Baby Boomers and the recognition of the lengthy time needed for an individual to develop this technical skill set contributes to increased hiring needs.

The Vacuum Technology program at Normandale is successfully educating a workforce to fill vacuum technician positions in local industries. And, the program has helped deepen the local pipeline for vacuum technicians by raising awareness and recruiting new students and by facilitating the placement of graduating students into local businesses. However, the Vacuum Technology program is small compared to other programs at Normandale. For example, the nursing and engineering programs enroll a critical mass of students, who cover the costs of offering courses. The small size of the Vacuum Technology program allows for personal instruction of complex material; but, as a low-enrollment program, Vacuum Technology loses money on its courses and must justify its existence within the constrained budget environment of the community college.

Project ReVAMP offered an opportunity to address national *and* local challenges. Vacuum-reliant industries around the U.S. need a pipeline of vacuum technicians with a solid grounding in science and math concepts, but few to no industries are able to benefit from local education opportunities like in Minnesota. The Vacuum Technology program at Normandale offers a formal program of study for vacuum technicians but needs to increase student enrollment to maintain the long-term viability of the program. The solutions, pursued during ReVAMP, were:

- To establish organizational relationships, *partnerships*, to increase student enrollment in the Vacuum Technology program, and
- To use telepresence technology to link distributed audiences with the formal vacuum technology education courses at Normandale.

D. Pursuing Partners: Early Planning, Early Assumptions, Early Successes

The Project ReVAMP project plan and budget supported work to establish partnerships in every year of the grant. Upon reflection, project staff agree that this was a wise allocation of time and money. For example, it took almost two years of the grant period to bring one of the academic partnerships to fruition. Delaying these activities until later in the grant period would have made it difficult for the project to accomplish Objective 3.

> **Lesson: Be aware of the implementation timeline. Start early and be intentional about planning for institutional partnerships.**

In planning the structure of partnerships to meet the national and local challenges described above, project staff started with an initial set of assumptions.

- Assumption 1: Pursue partnerships with businesses in vacuum-reliant industries *and* academic institutions; but, of the two, academic institutions were a higher priority because their interests, administrative structures, and student populations were aligned with Normandale's.
- Assumption 2: Pursue a financial and administrative model where partner institutions register their students or employees in Normandale courses thereby increasing enrollment in, and viability of the Normandale Vacuum Technology program.
- Assumption 3: Pursue a teaching and learning model where a vacuum trainer system is shipped to participants at off-site locations, so they can participate in hands-on learning.

These assumptions shaped Year 1 partnership activities, which included developing drafts of:

- A process map showing the flow of logistical arrangements that would be necessary to complete before offering a joint class with a partner(s).
- A financial model, with revenue and expense variables, for a single class that combined onsite students at Normandale and students or employees at partner institutions. ReVAMP staff used the model to predict minimum enrollment numbers that would be necessary to ensure the viability of partnership arrangements.
- A contractual agreement, which defined vacuum technology course partnership arrangements.

Of the ReVAMP staff members, Co-PI Nancy Louwagie led this work and was assisted by an employee in Normandale's Academic Affairs office. This individual was experienced in defining partnership arrangements with other post-secondary institutions and high schools to jointly offer academic programming in a defined Partnership Center located on the Normandale campus. Unfortunately, the staff member took another position and left the college mid-way through Year 1, so the dedicated effort to expand formalizing defined partnership arrangements stalled.

When the ReVAMP proposal was submitted, four post-secondary institutions had expressed interest in forming a partnership with Normandale. As the project progressed through Year 1, three institutions dropped off and one was added. The remaining academic partners were a community college and a small campus within a university system; both were not in Minnesota.

In spite of steady progress to prepare for partnerships at Normandale, circumstances at the academic partner sites were beyond the control of ReVAMP staff. They were dependent on administrative or personal choices that affected the overall rate of progress. For example, at the community college, the faculty member scheduled the 'partnership' *Intro to Vacuum Technology* (VACT 1292) course for joint delivery, but no students enrolled in the course. To maintain momentum, the faculty member observed the *Intro* class delivered from Normandale via telepresence in Fall 2015 and provided feedback about the experience. However, the faculty member retired in early 2016, and no further course partnership deliveries have been attempted with that community college. And, in another example, administrators at the small campus resisted the idea of enrolling their students in a course at Normandale. Resolving this issue took most of Year 2 and also caused a shift in the financial and administrative models in Assumption 2. The impacts on Project ReVAMP are described in more detail below.

Throughout Year 1 (2014-2015), ReVAMP staff made steady progress on project objectives 1 (revise courses) and 2 (build vacuum trainer systems). By Summer 2015, the redesigned course (*Intro to Vacuum Technology*, VACT 1292) and a newly designed high vacuum trainer system (HVET) were ready for implementation in a telepresence classroom. Testing the course, the HVET system, and telepresence delivery model *with any viable partner* became the top priority.

Project ReVAMP staff turned to their Industry Advisory Group, which was convened in Year 1 to provide feedback on the development of VACT 1292 and the HVET design. Representatives from industries in the Bloomington region, who were already familiar with the curriculum and the program, were interested in becoming partners.

Beginning in Summer 2015, a business in the hard drive industry enrolled 6 students in the inaugural VACT 1292 course delivered via telepresence. In spring semester 2016, summer term 2016 and fall term 2016, Normandale established partnerships with businesses in the semiconductor and hard drive industries. Below we discuss in detail the factors that enabled an easy "fit" between industry and Normandale, despite the early assumption otherwise. By Spring 2016, project staff had abandoned Assumption 1 (academic partners were a priority) and began to actively seek partners in industry.

> **Lesson: The long time horizon between proposal application and starting work on a grant affords plenty of time for circumstances and priorities to change. Identify more than one potential partner, make a backup plan, and be flexible, patient and open to challenging assumptions and adjusting plans as needed.**

This early and consistent success in forming industry partnerships in Year 2 yielded several outcomes:

- Proved that telepresence is a viable model for teaching and learning the complex concepts in vacuum technology;
- Proved that the HVET system could be shipped literally thousands of miles, reassembled and used in classroom demonstrations by off-site students, and safely returned to Normandale;
- Established workflow processes for rapidly onboarding cohorts of industry employees;
- Provided data to test the financial model for predicting the impact of partnerships on the viability of the Vacuum Technology program;
- Prompted discussions about whether pursuing academic institution partnerships was "worth it" given the time and effort required versus the positive reception from industry and ease of enrolling employees as students.

Entering Year 3, the contract and logistics with the sole academic partner were finalized, and a class was scheduled for Fall 2016. The demand from industry expanded beyond the businesses that participated in the Industry Advisory Group.

As a result of project dissemination activities at the American Association of Community Colleges Advanced Technological Education (AACC ATE) Principal Investigators Conference 2016, an entirely new type of partner expressed interest in the Vacuum Technology program and telepresence courses. During Spring 2017, representatives from two U.S. National Laboratories visited PI Smith and Co-PI Louwagie to review the Vacuum Technology curriculum, learn about the telepresence courses, and interview students and recent program graduates. A cohort of employees from Lawrence Livermore National Laboratory took *Intro to Vacuum Technology* (VACT 1292) via telepresence in Summer 2017. For Fall 2017, some individuals from that cohort are now taking *Vacuum Analysis and Troubleshooting* (VACT 2293) via telepresence while a new cohort is taking VACT 1292.

The rest of this report discusses the themes and lessons that emerged from all of the partnerships between Normandale, industry, and academic institutions.

E. Observations on Partnerships

The topic list below was generated from themes that emerged from the content analysis lite. We have included some anonymized quotes from interviews, which provide the perspectives of industry and academic partners, plus we report the experiences of ReVAMP staff.

1. Getting Buy-in
   1.1. Motivations for establishing a partnership
   1.2. Stakeholders in a partnership
2. Demonstrating telepresence technology in the classroom
3. Institutional Alignment
   3.1 Course & Class Schedules, Meeting Space
   3.2 Pedagogical Approach, Learning Management Systems, Textbooks
   3.3 Expectations & Etiquette
4. Staffing the telepresence classroom
5. Telepresence System & Room Design
6. Telepresence Cost
7. Vacuum trainer system
   7.1 Liability
   7.2 Scheduling & Shipping
   7.3 Ratio of students to vacuum trainer systems
   7.4 Cost

1. Getting Buy-in

Establishing partnerships with industry and community colleges to deliver *Intro to Vacuum Technology* (VACT 1292) via telepresence required a blend of sales and administrative finesse both at Normandale and at remote sites. "Getting buy-in" is a broad category. Interviews specifically described the *motivations* for pursuing partnerships and the *stakeholders* involved in moving from an idea to formalizing a partnership. There were significant differences between industry and academic sites in almost every aspect of obtaining buy-in.

1.1. Motivations for establishing a partnership

Industry sites saw the Normandale course(s) as a professional development opportunity that was offered by an accredited institution. The course content was immediately relevant to their vacuum technicians, and enrolling employees in VACT 1292 cost less than other training opportunities on similar topics. Industry sites already had meeting rooms equipped with telepresence technology, fast internet connections, and dedicated IT support staff. Since the Normandale and industry telepresence delivery systems were aligned, the start-up costs (i.e., learning curve with technology, room design, AV equipment) were minimal. And, businesses were willing to provide employees with onsite access to the telepresence meeting room once or twice a week rather than have employees miss days of work for training.

At academic sites, faculty members and some administrators saw partnering to offer VACT 1292 as an opportunity: to test their local telepresence technology installations; to offer a new course to students; or, to jump-start (and test the students' receptiveness to) a new program of study. IT staff at academic sites were also receptive to testing their telepresence systems in a classroom setting. Despite a willingness to try something new, there were very few workflow processes in

place to support a quick adoption / turn-around to establishing a partnership with another academic institution. And, some academic administrators saw no opportunities at all, instead seeing risk in equipment and safety liability and potentially extra costs and loss of revenue.

Observation: Establishing a partnership, especially with another academic institution, can be described as advocating for change. At a remote site, this required a dedicated and persistent champion to leap through bureaucratic hoops, cajole reluctant administrators, and expand thinking about new modes of teaching and learning. In hindsight, assembling a small team to support the partnership with Normandale might have distributed the workload and added more advocates.

Recommendation. When establishing an academic partnership, select a champion who is from the department that would host the course and who has a degree of seniority and is familiar with local policies and politics. And, establish a team comprised of representatives from: the business office (contract negotiations and accounting); human resources (assignment adjustments); IT support; and, admissions / registration.

1.2. Stakeholders in a partnership

In the early phases of planning for organizational partnerships Louwagie (Chair, Engineering Technology Programs at Normandale and Co-PI NSF-ATE DUE #1400408) devoted significant effort to developing a process flow-chart, a presentation that delineated institutions' responsibilities, and draft language to formalize a partnership. A benefit of this work was that administrative units at Normandale were aware early in the grant period, rather than receiving a last-minute surprise, that they might have to support new or different workflow processes.

An early assumption (noted above), which informed Louwagie's planning, was that students at other colleges or universities would enroll as Normandale students. However, feedback from a potential partner identified some of the challenges with this approach. Namely, students at the partner site might need to maintain full-time enrollment at their "home" institution to fulfill financial aid requirements. Enrolling as a Normandale student could have an immediate, negative impact on financial aid in this scenario.

Other challenges, raised by the financial office at the partner site, were: which institution would receive the students' tuition, and how would fees and costs be allocated? While Normandale needed off-site student enrollments to support the cost of teaching vacuum technology courses, potential partner institutions were unwilling to forego revenue from "their" students, who were onsite, using campus services. These challenges had a direct impact on the second assumption – that it would be easier for Normandale to establish partnerships with another academic institution because their administrative units were more closely aligned. While ReVAMP staff did not abandon their goal of establishing a formal partnership with another academic institution, they did adjust their expectations and timelines.

As ReVAMP and Normandale staff pivoted to work with industry partners, they drew on Louwagie's early planning work because industry partnerships aligned with the model of employees enrolling as students at Normandale. In spite of the planning, Louwagie expended a

considerable level of effort to sync industry and Normandale administrative expectations and infrastructures. Louwagie's efforts included:

- Providing extra support to managers, the Human Resources department, and employees (e.g., advising via telepresence or at business' location)
- Making the registration process easy and promoted or advised on appropriate registration choices (i.e., register as visiting student, audit or for-credit)
- Workings with the Normandale Registrar to accept employee registrations through the first week of class

The outcome of Louwagie's work with industry partners was to successfully demonstrate that telepresence is a viable model for delivering technical education and to successfully establish workflow processes for onboarding remote students that would offer some guidance to working with academic partners. This experience enabled Louwagie to offer advice and support to faculty at academic partner sites. However, the burden of the effort to establish a partnership fell to these faculty members. It took two years, from initial conversations to the first day of class, to establish a partnership with another academic institution. Table 1 provides a sample list of offices at Normandale and at industry and academic partner sites that have been involved in establishing a formal, organizational relationship.

Lesson: After two years of working to offer the VACT 1292 course with an academic partner, recruiting students was almost an afterthought. The lessons are to start marketing the course to students earlier (with student-specific messages) and to save some energy for the final push to get students enrolled.

Table 1. Sample list of offices or stake holders needed to establish an organizational relationship

Normandale	Industry Partner	Academic Partner
Normandale Liaison (PI, Co-PI)	Partnership Liaison (Manager)	Partner Liaison (Faculty Champion)
Instructor (scheduling course)	Partnership Liaison	Faculty Champion, Department Chair
Registration	Partnership Liaison	Registrar
Business Office (Quote for course, billing)	Business Office	Business Office
Shipping and Receiving (HVET and textbooks)	Shipping/Receiving	TBD
Lab Assistant (prep equipment for shipping)	Partnership Liaison	Faculty Champion
IT (test and support telepresence connection)	IT department	IT Services
Advisor (distance students)	Normandale Advisor	Faculty Champion
Dean's assistant (PO generation)	NA	Business Office
Students	Employees / Students	Students

2. Demonstrating telepresence technology in the classroom

This theme emerged from observing that at the two academic partner sites, both faculty champions attended (via telepresence) nearly an entire semester of *Intro to Vacuum Technology* (VACT 1292). And, the first industry partner assigned a senior technician to observe and provide feedback on the course delivery.

Because of the extended timeline for establishing academic partnerships, the faculty champions were able to observe classes in which industry employees and Normandale students were enrolled. The faculty wanted to learn about the course content and about how telepresence was used in the classroom. Specifically, they wanted to gain "further familiarity with the course materials and align my practicum development with the lectures for future use" and to gain "a further understanding of the capabilities and limitations of the [telepresence] system." In thinking about future partnerships, they observed that, "campuses new to the telepresence system may require more support from the project to effectively use this tool and understand its capabilities and the specific facility needs." Partners suggested hiring "a consultant focused on telepresence use to aid in communicating facility needs and to address questions from partner support groups" and providing "examples of other practices from past collaborations."

> **Recommendation: Some partnership questions might be addressed via a demonstration video.**

One benefit of having off-site faculty and technician observe classes was that ReVAMP and Normandale IT staff were able to test the telepresence equipment with more than one remote site at the same time. One of the questions about sustaining and scaling the Vacuum Technology program is: how many remote sites can participate in a course while still preserving the quality of teacher / student interaction? This is directly related to how the telepresence technology functions. Remote sites appear on a dedicated screen in the Normandale classroom. A video feed from just one site uses the entire screen. As more sites are added, the screen is split, and images of the remote sites become smaller.

> **Lesson: ReVAMP staff anticipate that three or four remote sites are the maximum that can be accommodated in one course before the interactive quality degrades.**

3. Institutional Alignment

One of the challenges in formalizing academic partnerships was that many of the start-up activities were interdependent with many mundane, but critical, details to manage.

3.1 Course & Class Schedules, Meeting Space

For academic partners, their observations in hindsight were that early in the process of obtaining buy-in, the faculty champion should simultaneously begin *aligning course schedules and securing a telepresence facility* on campus. In fact, one faculty champion suggested this should be "done first because it was critical."

For example, after two years of negotiating the details of a contract between Normandale and an academic partner, on the first day of the joint class, the off-site faculty member realized that Normandale classes begin at the top of the hour; at the remote site, classes begin ten minutes

after the hour. The off-site students agreed to meet ten minutes earlier, but after two years of work, this detail had the weight of the proverbial straw on the camel's back.

At industry sites, scheduling was not an issue. In fact, managers were pleased that employees did not have to miss an entire day of work and did not incur travel costs associated with other training opportunities.

3.2 Pedagogical Approach, Learning Management Systems, Textbooks

One of the motivations for redesigning *Intro to Vacuum Tech* (VACT 1292) was to incorporate the pedagogical principles of active learning and flipped classrooms. The revised content and teaching / learning activities are embedded in the structure of the learning management system (LMS). Making the LMS central to the course ensures that onsite and off-site students have equal access to the course materials.

While exploring the possibilities for an academic partnership, ReVAMP staff and a faculty champion learned that, while the textbook and syllabi were aligned, each academic institution used a different LMS. The partnership did not proceed for several reasons, but ReVAMP staff and the faculty champion realized that not using the same LMS is significant obstacle for any partnership.

The proprietary structure of LMS's make exporting course content and installing it on another system time consuming and expensive. But, the bigger reason behind aligning LMS' between academic partners is that, so far, administrators have been unwilling to lose tuition fees by having their students enrolled in Normandale classes.

For industry partners, aligning LMS or textbooks was not an issue. Employees were enrolled at Normandale and given logins to the LMS.

> **Lesson: Asking potential academic partners about their LMS is another critical first step in a partnership.**

> **Observation: The lack of "portability" of course materials from the Normandale LMS may limit the types of partnerships ReVAMP staff can accommodate. Organizations will have to already share the same LMS or students / employees will have to enroll in Normandale classes.**

3.3 Expectations & Etiquette

Another issue, somewhat related to educating new partners about telepresence, is aligning expectations about the functionality of telepresence and how that influences teaching and learning activities and social interactions in the course. What emerged from interviews and reports was that faculty champions and students had to overcome their past experiences with video technology, which primarily involved passively watching a screen.

Faculty champions needed to observe several class sessions to understand how the Normandale instructor used the real-time telepresence connection to engage students. And ReVAMP staff observed a range of reactions and behaviors from off-site students / employees. Some off-site

students treated the telepresence classes like a one-way feed of a video lecture, not using the real-time connection, microphones, and cameras to engage with the instructor. In one case, the off-site faculty had to encourage students to turn on their microphones and ask questions; they were intimidated by the technology. At industry sites, sometimes the opposite occurred. Employees engaged in distracting behavior and side conversations while video cameras made their actions visible to the instructor and students at Normandale.

> **Recommendation: Early in a telepresence course, demonstrate the functionality of the technology and provide expectations and encouragement for onsite and off-site student participation.**

4. Staffing the telepresence classroom

Throughout Project ReVAMP, the faculty champions who helped shepherd academic partnerships were also the people who staffed the classes when they were finally held. With industry partners, the employees who attended classes managed their own IT connectivity and HVET setup.

Both industry and academic partners provided a considerable amount of feedback about how to staff an offsite class. This is a high priority issue because staffing is a factor in scaling the vacuum technology courses. And, staffing options highlight some of the trade-offs involved in telepresence education. Some parameters that shape this issue:

- Staff time is one of the largest costs associated with teaching the vacuum technology courses at Normandale. The motivation for scaling up the number of off-site partners and enrolled students is to cover the costs of a Normandale instructor.
- Having a faculty member staff an off-site class is expensive and redundant and is a disincentive to forming a partnership.
- Activities to be managed at an offsite classroom: classroom management (includes modeling expected "on-screen" behavior); proctor exams; interface with IT staff.
- At every offsite location, someone needs to be responsible for the HVET system: receiving / shipping / packaging; assembly; preparation / monitoring class demonstrations and use / storage; and, troubleshooting and repair.

In feedback and subsequent conversations, several ideas were put forward for staffing academic partner sites, such as having an adjunct instructor, lab assistant or student worker fill the role previously held by a faculty champion. Any solution would have to accommodate faculty and union contracts, scheduling, and student competency. With industry partners, staffing the telepresence classroom is less of an issue: employees / students are more mature and should require less oversight; HR or training departments are capable of proctoring exams.

> **Observation: Both ReVAMP staff and academic partners realize that the Vacuum Technology courses will not be sustainable or scalable if they are staffed by faculty members or faculty champions.**

5. Telepresence System & Room Design

One of the purposes of Project ReVAMP was to test the viability of telepresence in the classroom, especially for teaching complex terminology and concepts that require real-time discussion with an instructor. Over the duration of Project ReVAMP, we have tested telepresence technology in 9 classroom scenarios. Through self-assessment and with feedback from academic and industry partners, we have developed some insights on room design and technology, equipment, and furniture configurations that have had a positive impact on our experiences teaching and learning in the telepresence classroom.

The telepresence systems of academic partners were installed in large halls or Maker Spaces. With industry partners, the systems were installed in conference rooms. In these installations, the telepresence systems were designed to support real time interaction in administrative or executive meetings, lecture classes with a video component, or meetings with demonstrations via video. The systems and spaces were not designed to support interactive teaching and hands-on learning for onsite or off-site students.

ReVAMP staff gained experience teaching in spaces that were less than ideal for telepresence. For example, at some industry sites, the two academic sites, and the first classroom where ReVAMP staff held a telepresence class at Normandale, the spaces were not optimal. Feedback from multiple partners was that the rooms where telepresence equipment was installed "was not a classroom." The solution for Normandale was to use funds from the Minnesota Leveraged Equipment incentive program and to work with Normandale IT staff to design a telepresence system that was customized for the Normandale vacuum science lab (see Figure 2). Based on this experience and working with partners whose telepresence systems and classroom spaces varied, the ReVAMP staff developed a checklist of features to control for, or at least be aware of, both for onsite and off-site telepresence partners.

- **Size of meeting space**: One partner, meeting in an auditorium lecture hall that seated 50, noted that the class of six students "felt like an audience in our room."
- **Acoustics**: Another partner met in a Maker Space and had to contend with background noise from ventilation systems and machinery plus the acoustics of a big room with hard surfaces.
- **Furniture**: Several partners met in spaces with furniture that could not be moved, which affected how the camera was positioned and how the students appeared onscreen at Normandale. Or, students were seated at fixed desks while the HVET system was placed across the room.
- **Equipment**: As the number of partners has expanded, ReVAMP staff members have partnered with sites that do not have a Cisco telepresence system but that do have many of the components. One partner had only one video feed from a small conference room. Even though the students had an HVET system and used it during demonstrations, the instructor at Normandale never saw the HVET because it was off-camera at a side table. Also, in this instance, the network speed was too slow to support good video imaging.

After much discussion, ReVAMP staff have identified the following minimum technology requirements for partner sites:

- Two monitors, one to view the instructor and classroom and one to show content (e.g., PowerPoint slides, whiteboard, or HVET demonstrations) at Normandale;

- One camera at the remote site to provide a view of the students and the off-site HVET to the instructor at Normandale;
- A further recommendation is to pick a "right-sized" room that accommodates the number of offsite students and HVET system and that has movable furniture.

Figure 2. Telepresence @ Normandale
The custom telepresence system at Normandale was designed by Tam Huynh, the Normandale Educational Technology Engineer. The system consists of

- Three large high definition monitors, one of which is a touch screen;
- Three high definition cameras;
- High-performance microphones and speakers.

The system is controlled by a touch pad at the instructor's location. Two cameras in the front of the classroom, located between two 75" monitors, respond to sound and will automatically focus on whoever is speaking. The third camera and a 55" monitor are located at the back of the classroom. All three cameras are controlled by the touch panel at the instructor's location, and can be directed at, and zoomed on, demonstrations, displays and lab operations.

6. Telepresence Cost

Partners did not provide much feedback about the costs associated with their telepresence systems because the technology was already installed. Normandale was the only institution to design and install a telepresence system to specifically meet the need for teaching vacuum technology courses. However, over the course of establishing partnerships, ReVAMP staff observed other costs associated with using telepresence systems. These costs are mostly associated with academic partnerships, though industry partners are sensitive to the overall costs associated with the telepresence technology.

- **IT staff**: Ideally, a dedicated staff member would be available to troubleshoot issues as they arose during class. For academic partners, sometimes the faculty champion did some of the IT startup / shut down work. This might be an activity that an adjunct or student worker could fulfill, which is a factor to consider when scaling up the number of partner sites.
- **Admin staff**: As noted above, scheduling the facility that has telepresence technology is a critical first step. There is still some administrative overhead in defending the space.
- **Faculty / Manager**: There is a time cost in the incidentals of making the telepresence system work for each class period and also in understanding how the telepresence technology features can be used in teaching. A student worker might not be able to fill all of those roles.

Interviews indicated that none of the partners had serious problems with their telepresence systems during classes. In fact, Louwagie confirmed that over seven semesters, no class was ever cancelled due to technical problems with the telepresence systems.

> **Lesson: With some focused discussion during the planning stages of a partnership, some of these costs could be mitigated or, at least, factored into an operating plan and budget.**

> **Recommendation: Based on their experiences, ReVAMP and Normandale IT staff should develop a template for a backup plan in case of technology failure. Each partner should complete this plan prior to the start of classes.**

7. Vacuum trainer system

In the ReVAMP proposal, Normandale staff identified hands-on learning as a key component of vacuum science education. The vacuum systems used in advanced manufacturing are expensive, complex, and often situated in "clean rooms." Technicians wear scrubs or "bunny suits" to maintain a sterile environment. And when a vacuum system is offline, even for a few hours, it can cost businesses millions of dollars. There is little room for error when learning on the job, but there are few opportunities for vacuum technicians to develop knowledge or practical skills outside of the workplace.

For ReVAMP staff, the solution to providing hands-on learning in the classroom was to design and build a High Vacuum Education Trainer (HVET) system that has few limitations on where it can be used. When redesigning the curriculum for *Intro to Vacuum Technology* (VACT 1292), demonstrations and experiments were regularly included to give students the much-needed opportunity for practice with the equipment. To accommodate offsite students, ReVAMP staff built multiple copies of the HVET system. And, with matching funds from the Minnesota

Leveraged Equipment incentive program, staff also designed and built a Rough Vacuum Equipment Trainer (RVET). There are now seven vacuum equipment trainer systems (3 HVET, 4 RVET), and with DELIVER, staff will have up to 10 vacuum trainer systems with modular components that can accommodate students' progression of skills and concepts through the three-course Vacuum Technology certificate (see Figure 3).

Figure 3. Vacuum Equipment Trainer Systems @ Normandale

Rough Vacuum Equipment Trainer (RVET) System with 2 Torr base pressure capability

RVET made possible with funds from the Minnesota Leveraged Equipment incentive program

- 3 total systems
- Supports basic vacuum science demonstrations (e.g., boil water, blow up balloon, reduce sound volume)
- Transportable
- Diaphragm pump
- Convection gauge
- Industry grade components

High Vacuum Equipment Trainer (HVET) System with 5x10-6 Torr base pressure capability

HVET made possible by NSF DUE #1400408

- 4 total systems
- Supports demonstrations of vacuum technology operation (gas sensitivity, leak testing, RGA, plasma)
- Use for hands-on work with vacuum technology (pumpdown sequence, pumpdown curves, rate of rise, conductance)
- Transportable
- Scroll pump; Turbo pump
- Ionization gauge; Convection gauges; Piezo-electric gauge
- Capacitance manometer
- Gate valve
- Mass flow controller
- Industry grade components

The reason why multiple copies of the HVET systems have been created is to accommodate multiple offsite partners. During the course of ReVAMP, every offsite partner has had access to the trainer systems. Project funds have fully covered packaging, shipping, and insurance. When thinking about scaling up the number of partners to sustain the Vacuum Technology program, ReVAMP staff are exploring the extent to which partners would need to pay a fee for using the trainer systems (e.g., a rental fee, contract for coverage of damage, and shipping). Feedback from academic and industry partners have provided insight into the issues that inform scaling and effectively using the HVET / RVET systems with future partners.

7.1 Liability

The faculty champions at academic institutions encountered administrators who were concerned about being liable for equipment that cost ~$10,000. Administrators were also concerned about student and facility safety since the trainer was to be used in a lecture hall rather than a lab. Industry sites had few qualms about their employees using an HVET system in a meeting room because staff already had some experience using vacuum systems.

7.2 Scheduling & Shipping

In a few instances, HVET trainers arrived to offsite partners just as VACT 1292 classes were beginning. Those students who were not able to use the HVET from the first day of class remained intimidated by the equipment and were reluctant to use it for the rest of the semester. A make-up telepresence session with the Normandale instructor might have mitigated some of this hesitation.

7.3 Ratio of students to vacuum trainer systems

Another observation from academic partners that relates to scaling up enrollment is that one trainer system can accommodate about four or five students for hands-on experiments. For example, one faculty member noted that an effective HVET demonstration involved a group of four students with roles that each student rotated through: giving directions about a sequence of activities, operating the machinery, taking readings from gauges, and observing the entire process and providing feedback. If an academic partner enrolls more than six students in one course, then the costs for scaling might increase because of the need to ship and insure another vacuum trainer system and possibly fund another position to manage the system and guide students during classes.

Observation: The optimum ratio of students to vacuum trainer systems is 4-6 to 1.

Recommendation: Early in the partnership planning process, develop a shipping and assembly schedule to ensure the vacuum trainer systems are ready to be used in the first class period.

7.4 Cost

For the duration of Projects ReVAMP and DELIVER, the cost of packaging, shipping, maintaining, and insuring the VET systems are supported by the grant. However, in exploring sustainability models, ReVAMP staff realize these costs will have to be borne by partner institutions, perhaps as one-time rental fees or as a longer-term lease. Another factor that affects cost is the duration of a partnership. So far, academic and industry partners have enrolled students or employees for a one-semester course. However, once the three-course certificate is available via telepresence (estimated Fall 2018), partners might want to keep the VET systems for an entire year. And, if some partners envision that employees will regularly take vacuum science courses from Normandale, they might want to buy one of the VET systems.

Next Steps

This section summarizes the recommendations to ReVAMP staff that were provided in interviews. This section also synthesizes the lessons learned from above and suggests recommendations for how Normandale staff could proceed to operationalize this information in support of Project DELIVER.

Recommendations from interviews

The ReVAMP staff should "hire someone who is dedicated to talking to partners about telepresence, establishing a partnership, and onboarding issues so that the team [at Normandale] can continue to focus on content development."

"Provide expectations for etiquette and remote / local interaction."

"Develop a packet of information for future partners that address the following areas:

1. Facility requirements and support for Cisco Telepresence
2. Student enrollment and registration and materials delivery
3. Faculty Contractual and Procedural Agreements
4. Further Use and Development of the Vacuum Trainer"

And regarding future course development or refinement, "use animations; show actual physical components rather than pictures."

Summary of Lessons

Below are the observations, lessons, and recommendations for partnerships that are found throughout this report. Below, the statements have been grouped into two areas: *A. Improving the partnership start-up process* and *B. Planning to scale partnerships*.

A. Improving the partnership start-up process, especially for academic institutions

Lesson: Be aware of the implementation timeline. Start early and be intentional about planning for institutional partnerships.

Lesson: The long time horizon between proposal application and starting work on a grant affords plenty of time for circumstances and priorities to change. Identify more than one potential partner, make a backup plan, and be flexible, patient and open to challenging assumptions and adjusting plans as needed.

Observation: Establishing a partnership, especially with another academic institution, can be described as advocating for change. At a remote site, this required a dedicated and persistent champion to leap through bureaucratic hoops, cajole reluctant administrators, and expand thinking about new modes of teaching and learning. In hindsight, assembling a small team to support the partnership with Normandale might have distributed the workload and added more advocates.

Recommendation. When establishing an academic partnership, select a champion who is from the department that would host the course and who has a degree of seniority and is familiar with local policies and politics. And, establish a team comprised of representatives from: the business office (contract negotiations and accounting); human resources (assignment adjustments); IT support; and, admissions / registration.

Lesson: After two years of working to offer the VACT 1292 course with an academic partner, recruiting students was almost an afterthought. The lessons are to start marketing the course to students earlier (with student-specific messages) and to save some energy for the final push to get students enrolled.

Lesson: Asking potential academic partners about their LMS is another critical first step in a partnership.

Lesson: With some focused discussion during the planning stages of a partnership, some of these [staffing] costs could be mitigated or, at least, factored into an operating plan and budget.

Recommendation: Early in the partnership planning process, develop a shipping and assembly schedule to ensure the vacuum trainer systems are ready to be used in the first class period.

Recommendation: Based on their experiences, ReVAMP and Normandale IT staff should develop a template for a backup plan in case of technology failure. Each partner should complete this plan prior to the start of classes.

Recommendation: Early in a telepresence course, demonstrate the functionality of the technology and provide expectations and encouragement for onsite and off-site student participation.

Recommendation: Some [new] partnership questions might be addressed via a demonstration video.

Next steps for improving the partnership start-up process

Combined with the specific recommendations from interviews, the near-term next step seems to be to: develop a handbook on partnerships to provide guidance on the start-up process through the conclusion of a course. In addition to timelines, checklists of administrative offices, and backup plans, the handbook might also provide a list of marketing tools or strategies to reach students. The primary audience for this handbook would be potential academic partners.

Industry partners did not indicate a need for a handbook in part because ReVAMP staff, in particular Nancy Louwagie, have worked to make enrollment a seamless process. In this case, codifying a successful process might primarily be of use to Normandale administrative staff while also being a sales tool for potential industry partners.

B. Planning to scale partnerships to sustain the Vacuum Technology program:

Observation: The lack of "portability" of course materials from the Normandale LMS may limit the types of partnerships ReVAMP staff can accommodate. Organizations will have to already share the same LMS or students / employees will have to enroll in Normandale classes.

Observation: Both ReVAMP staff and academic partners realize that the Vacuum Technology courses will not be sustainable or scalable if they are staffed by faculty members or faculty champions.

Lesson: ReVAMP staff anticipate that three or four remote sites are the maximum that can be accommodated in one course before the interactive quality degrades.

Observation: The optimum ratio of students to vacuum trainer systems is 4-6 to 1.

Next steps for scaling partnerships

These observations provide numbers and estimates that are derived from ReVAMP staff and academic partners' experience. Having hard data is invaluable and makes it possible to develop a baseline model for sustainability. What also emerges from the themes above is that pursuing partnerships with academic institutions takes years and a significant amount of effort before a course is delivered. However, the time it takes to formalize a partnership with a business can be measured in months. There are trade-offs for Normandale with each type of partnership, which are summarized in the table below. The factors are provided by Nancy Louwagie at Normandale.

Table 2. Factors that Impact the Costs and Benefits of Partnerships

Partnership Factors	Industry Partner	Academic Partner
Lead time to formalize partnership	1-3 months	1-4 years
Effort to support formalizing new partnership (on Normandale's part)	Medium (20 hours); workflow is established, little variation	High (40 hours); no workflows; needs / concerns are unique to each institution
Effort to enroll students (on Normandale's part)	High (20 hours)	Low (0 hours)
Duration of partnership	1-2 semesters (so far)	1 semester and counting; after effort to establish partnership, Normandale course will continue to be offered
Revenue generated for Vacuum Technology program (per partner)	$4-8K	$0
Receptiveness to VACT courses	Extremely positive	Beyond faculty champion, lukewarm to opposed

Conclusion

As Project ReVAMP draws to a close, Normadale staff feel optimistic about the trajectory of the project as it segues into DELIVER. The proof-of-concept ideas and processes in the ReVAMP proposal are viable. DELIVER provides the opportunity to complete the redesign and delivery of the courses that will allow employees or students to earn a Vacuum Technology certificate. With this "package" of content, ReVAMP / DELIVER staff will be able to present a compelling argument for why industry and academic institutions should partner with Normandale. And throughout DELIVER, staff will actively explore how to scale new and existing partnerships as a strategy to sustain the Vacuum Technology program for the future.