Broadening Participation through Engagement in the Maker Space Movement

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Broadening Participation through Engagement in the Maker Space Movement

The needs are endless when we encourage engineering creativity through applications. In the past few years, the creation of tech shops or maker spaces has been a boon to engineering innovation, and has particularly contributed to strategies to broaden participation in engineering majors. In the past year, the authors have been managing the creation of such a space within a minority-serving land-grant institution. The advantages of low-resolution tryouts and prototyping being added to the engineering curriculum are abundantly discussed elsewhere. In this paper, we discuss the creation of a maker space and how we have used it as an adjunct to our college's engineering and engineering technology curricula. The issues of resources (human and financial), assessment, and the proper role of the maker space have evolved over the six months the space has been active.

Planning such a space is a traditional activity. Visions of its use may, however, be optimistic and pessimistic at the same time. How students use the space has surprised both faculty and college administration. Our goal has been to use the space as an organizing concept for a diverse array of activities ranging from high school robotics competitions to senior capstone projects. Subsequent to its introduction in February of this year, a study was conducted of student awareness. This study informed us of the increased challenges in marketing the use of the space. We have evolved a mentorship program to support students working in the space. The past six months have seen overuse by classes, exciting design competitions, and a few misuses. As we look to begin our second year of operation, we can report on some lessons learned, the roles of our corporate partners and the excitement of watching students develop ideas.

Introduction

The ability to provide educational opportunities that enable students from ethnically and economically diverse backgrounds to effectively compete in and contribute to a global economy is paramount in today's global society. At New Mexico State University, the College of Engineering has embraced the current maker space movement as a means of broadening participation in STEM fields and strengthening persistence and retention through graduation.

New Mexico State is a large, land-grant public institution of higher education with more than 13,000 undergraduate students. With a Hispanic population that comprises nearly 50% of the student body, New Mexico State is designated a Hispanic Serving Institution and is home to the state's oldest and largest engineering program (more than 2,600 students). Within the College of Engineering, strong collaboration and alignment between STEM outreach and public service programs and the engineering academic curriculum has contributed to stable enrollments in engineering amid three years of declining enrollments in all other degree disciplines at the

institutional level. In spite of these stable enrollments, the College has been confronted with the harsh realities of declining budgets and a growing need to engage enrolled students in experiential real world engineering experiences. With robust corporate partnerships in place, the College began to explore opportunities to leverage these partnerships as a means of broadening student engagement.

Amid an explosive interest in so-called maker spaces or "tech shops" in colleges of engineering across the country over the past five to ten years, New Mexico State's College of Engineering set about planning a maker space for undergraduate students to fill a need for broader student engagement. In doing so, we sought the advice of many, conducted site visits to existing maker spaces and then thought deeply about available space as well as the corporate support that would be required to create such an opportunity. With students across all engineering disciplines embracing this new wave of innovation and entrepreneurship, the challenge fell on the College to support this growing interest in a meaningful, relevant, and sustainable manner.

Creating such a space is a complex task but the authors used it as an opportunity to reframe the undergraduate educational experience for our students by pivoting academic preparation from a traditional deductive sequence to a networked, system-based inductive curriculum for developing professional competencies. This initiative focused on increasing enrollment and completion of a critical demographic that comprises under-represented, under-prepared, and/or low-income students through the unique integration of networked "evidence of promise" strategies in support of an innovative and inclusive engineering curriculum. Engineering programs across the country have adopted individual evidence-based strategies to meet very specific outcomes, but a need exists to reframe the undergraduate engineering and engineering technology curricula experience at the program level. In doing so, the authors focused adapting various curricula to meet educational program objectives.

Innovation Space Overview

The drastic changes that the workforce has seen since the mid-20th century is now requiring more than just the standard technical skills. The economy now requires greater social skills, teamwork, cognitive abilities, and technological skills.[7] As a result of the increasingly complex and multi-dimensional environment, innovation must exist in order to maintain competitive advantages. The infrastructure of an innovation space must be correspondingly multi-faceted to achieve this goal. An innovation space must have the appropriate physical, computational, and collaborative/social infrastructure.[9]

In his description of how knowledge and innovation is transferred from universities to industries, Phillips[11] notes that the most common methods are the "university spin-off companies" where an idea or invention conceived of by a student, faculty, or staff member is "exploited," and workshops, where industry and academia share their respective research.

However, Phillips notes that his belief is that "problem-driven research" – where a university and industry partner are working in conjunction to solve a particular problem that the industry partner is facing – has the highest probability of success. All three of these methods may be achieved in an innovation space, given the right characteristics.

Gassmann, Enkel, and Chesbrough[5] further elaborate on this concept of "open innovation," where they describe the trend of industry partners building research labs on university campuses to supplement their dwindling on-site research. This concept can be mutually beneficial to the industry partner's dwindling R&D departments, while help alleviate (particularly for public universities) limited academic research funding.

In addition to utilizing an innovation space for nurturing entrepreneurial efforts in undergraduate students, faculty and graduate students can benefit greatly. These innovation and entrepreneurship programs can be utilized to make them understand the social and market relevance of their pre-existing research.[10]

Further, the appropriate resources and infrastructure existing and being available to students, faculty, and mentors, innovators must be effective in their resource utilization, and while flexibility and the ability to change and adjust as needed are important, there still must exist a certain structure that allows for tracking and a "checks and balances" system that allows for any problems with projects to be detected early on.[6] Dhillon[4] agrees when noting that a key element of innovation is to allow for creativity (but not too loose of a structure); essentially, what is needed is the "the appropriate balance between 'organic and mechanistic' options." This can be provided by the engagement of skilled, trained, and technologically engaged faculty and staff.[1]

Innovation Space Challenges

Setting up a thriving innovation space requires multiple actions. First and foremost, policies must be in place which allow the space to exist. Funding (grants, venture capital, loans, etc.), industry and private stakeholders, contractual issues (particularly with intellectual property rights) must all be established with the inception of an innovation space.[12]

Phillips[11] notes that academic departments that are not equipped to carry out research and innovation in multi-disciplinary areas may be reluctant to implement innovation activities. This may require an organization within the college or university to be created to manage risk. Since federal funding can be elusive, the implementation of such organizations requires a "top-down" commitment from deans and departments heads.

Additionally, innovation spaces require the appropriate higher education culture that will establish the requisite policies and processes that nurture the innovative and creative process, and

will provide no more than a manageable level of resistance to change. Students must be recognized as having diverse needs, skills, and abilities, and must be given the appropriate access to innovation space resources. Given the entrepreneurial nature of innovation spaces, intellectual property rights regulations and policies must be strictly adhered to.[1]

Further, issues might include limited funding or the fact that there may be innovation opportunities that are not considered in scope of funding. Space limits might also be a constraining factor; problems arise with resource constraints if spaces are not flexible enough or do not have proper equipment and tools – must help test, build, and manufacture in small scale. Finally, contractual issues might arise in reference to conflict of interest between the school and partners, academic integrity, or intellectual property rights.[2]

The competition between a student's more traditional curriculum and innovation and entrepreneurial efforts can be problematic. Students may already have time constraints with formal coursework, and may be reluctant to pursue projects which do not count towards their degrees. One way to resolve this issue is to integrate these topics into the curriculum, such as in the form of offering a minor in innovation and entrepreneurship.[2]

Innovation can also be a challenge if students do not feel connected to the real-world issues that are arising outside of the walls of academia. Outreach programs that build community, global, and industry partnerships, can help alleviate this problem. The additional challenge of keeping students informed of resources available, and how to access and use them can also present itself.[2]

Alumni are often not utilized as well as they could be in conjunction with innovation spaces. MIT, for instance, is looking into utilizing alumni around the world to provide spaces for MIT graduates with an entrepreneurial focus. Building digital connections and putting in a funding support infrastructure are also aspects that alumni can be used for the innovation efforts.[2]

Our analysis of existing maker spaces, available space on campus, and our goals to improve opportunities for our students resulted in the creation of the New Mexico State conceptual design for implementation. This was a four-part set of opportunities to be offered to students. Specifically: we wanted to offer low-resolution prototype opportunities, provide effective coaching, create public-private engineering design challenges, and create a venue for co-curricular non-credit workshops on topics of interest to engineers and entrepreneurs. These goals set us on a journey that started with acquisition of a physical space along with attracting corporate and university support.

Creating the Space

Creating the innovation space was nearly a yearlong endeavor. Several key factors enabled the space to become a reality. First, it was the composition of people who initiated the idea. It began to develop into a concept during biweekly meetings between a highly engaged and strategically focused associate dean who oversees outreach and public service for the college, a highly experienced department head, a caring and progressive tenured full professor, and a newly hired assistant professor. The meetings were intended to spur innovation across the college and in alignment with an on-campus startup incubator. The associate dean wanted to create a space where students could gather individually or in groups and work on projects. The assistant professor wanted a lab that was similar to what he had in industry – one that would enable him to drive innovation through collaboration with students and faculty. The full professor – also director of the on-campus manufacturing center – was mentoring the assistant professor and helping him establish himself in the academic realms of the college. The department head understood the bureaucratic intricacies of the university and was respected by many across the college and the campus for his efforts in initiating entrepreneurial programs. These four individuals created a formula for success – pull from up top, experience with industry's best practices, open-minded support, willingness to integrate into the curriculum, and a knowledgeable navigator of bureaucracy. The team approach ensured that varied ideas were evaluated and created a leadership team that shared responsibility for addressing the multi-faceted issues required to create an effective and integrated space that ensured buy-in from all stakeholders (administration, faculty, staff, students, and industry).

During a series of biweekly meetings, through brainstorming, the idea of creating a makerspace, or an innovation space came to fruition. It quickly became clear that there needed to be buy-in across the college. To create buy-in and generate support, a few brown-bag lunches were held to seek faculty and staff input on what they thought would help drive innovation in the college. Attendance and engagement exceeded expectations. Nearly every department was represented and most attendees shared their opinions. The input from faculty and staff pointed towards the need for a space that was conducive to collaboration and supported innovation.

Soon the dean of the college became a supporter, which helped the team make significant progress. Most notably, it helped the team secure physical space within the college. As with many colleges, space is a hot commodity. A space of adequate size that was soon going to be vacant was identified. The physical layout of the space included a large open area, several average sized offices, a conference area, and a small break room. With support from upper-administration, a formal request for the space was submitted and subsequently approved. Planning for the new Aggie Innovation Space was now underway. Engagement becomes a goal.

To help ensure the space was effective. The team researched best practices and traveled to a few world-famous "innovation spaces." The team went to the Bay Area to meet with researchers at Stanford's d.school, venture capitalists on renowned Sand Hill Road, operators of

Tech Shop San Francisco, and even toured the underground hackerspace, Noisebridge. The trip was enlightening. It helped refine the vision for the college's innovation space, as well as build a strong bond between the team members. An important take-away from the site visits was to distinguish and allocate funding between the "political space" and the "functional space." Political space was defined as one that meets the needs of institutional marketing and high-profile visits but doesn't necessarily cater to the needs of the students. The functional space was defined as one where the "rubber meets the road" and tailors itself to the direct needs of students (white boards, gathering space, rolling carts, etc.). In an ideal world, one can accommodate both but when faced with space and budget constraints, student needs were given priority.

As soon as the previous tenants vacated, work began to create the space. An estimate was obtained from campus facility services to remove the fixed walls and replace them with movable walls that would "open" up the space to increase functionality. Plans were shattered when the team found themselves with a remodel estimate that far exceeded available funds. Acting on the advice to create "functional space" that was received during previous visits to maker space facilities, the team quickly regrouped and made a conscious decision to leave the fixed walls in place and "live in" the space before spending limited funds on what quickly became viewed as a possibly premature remodel. Subsequently, the team reverted to old-fashioned "sweat equity" and sought buy-in and ownership among the student body, with several students recruited to physically work alongside the assistant professor. A modest budget was made available by the associate dean to paint walls, strip carpets and replace them with garage floor coating. The summer was spent getting things ready for the fall semester. Students learned the value of "sweat equity," they were proud of the space they helped create, and they truly had a sense of ownership. Engagement had begun.

One of the most critical steps to ensuring the success of the space was to get buy-in from the faculty. An advisory committee, comprised of faculty and staff from every department in the college of engineering, the marketing department within the college of business, the on-campus startup incubator, and later the art department, was established. The committee was comprised of individuals who voluntarily championed the ideas espoused by the maker space concept of student engagement through innovation and entrepreneurship and who were committed to integration of the space within and across the engineering curriculum. The committee agreed to meet monthly during the academic year to evaluate equipment needs, listen to reports on facility usage, and actively develop educational programs to foster innovation and entrepreneurship among the student body. Through funding made available by the Halliburton Foundation, faculty members from the committee were able to travel to professional development courses to enhance their respective knowledge in emerging pedagogy surrounding innovation and entrepreneurship. Engagement became integrated.

An operations manager was retained through the associate dean for outreach and public service to manage the day-to-day operations of the new Aggie Innovation Space with engineering students hired to help staff the space. As a means of ensuring long-term

sustainability of the space, an operations plan was developed to guide inventory management and safety within the space.

This finally led to the opening in February 2014 of the "Aggie Innovation Space presented by Intel" at New Mexico State University College of Engineering.

We publically stated our goals as:

- Creation of a learning environment that invites innovation, ideation, creativity and entrepreneurship;
- Creation of non-credit, co-curricular educational programs to augment student learning (critical thinking, team work, hands-on experience, communication skills, etc.);
- Access to experienced mentors who nurture the use of technology and encourage discovery;
- Access to 3D printing and other engineering design tools to make the creative process come to life; and
- Creation of a pathway to new business startup.

Educational programs were developed and adopted with signature programs being the creation of Aggie Innovation Design Challenges (one-day team-based challenges presented by industry) and Aggie Innovation Pop-Up workshops (non-credit workshops designed to jump-start student engagement in a particular topical area). Faculty members volunteered to serve as liaisons with industry for the design challenges to ensure alignment with the engineering curriculum (common software, equipment, etc.) and to teach Pop-Up workshops. Educational programs are announced to all engineering students via email with no-cost on-line registration offered on a first-come, first-served basis. On-line registrations for the offered programs fill within days of announcement. Engagement had been embraced.

Funding the Space

A review of best practices revealed the need to create effective public-private partnerships that would position the space as a bridge from classroom to real world. Concurrent to engagement of students and faculty in creating the space, the associate dean for outreach and public service initiated an effort to engage corporate partners in funding the space. The prospect of broadening student engagement in engineering through innovation and entrepreneurship piqued the interest of several with Intel Corporation being first to actively partake in the new venture. Representatives from Intel's fab facility in Rio Rancho, New Mexico played a major role in helping to bring the space to fruition. The company provided seed funding to help acquire 3D printers, electronic equipment, hand-tools, white boards, computers, software, printers, and other consumables necessary to prepare the space for students to engage in hands-

on innovation. Intel's initial funding was followed by a commitment from New Mexico State's President's Performance Fund, and an additional pledge from Intel to help offset the cost of additional equipment and consumables over the next three years. Intel also provided an in-kind donation of 50 Galileo development boards to jump-start student innovation. A partnership was developed with New Mexico State's Arrowhead Center, the institution's technology commercialization division and business incubator, to leverage entrepreneurial programs through an already established student incubator. Interest in the emerging facility began to gain traction within the institution as well as among alumni and external partners. Additional corporate partners began to emerge including, Boeing, Western Refining, Cummins, TRAX International, and Sandia National Laboratories/Lockheed Martin, with each expressing interest in broadening participation in engineering among New Mexico State's highly diverse student demographic. Alumni became engaged through a new alumni fund at New Mexico State's Foundation to support the Aggie Innovation Space. Alumni employed within various corporate partners became champions for the emerging collaborations being formed.

Through funding provided by the Halliburton Foundation, five (5) faculty members were trained in the Lean Launchpad product development methodology, which is used throughout the respective advising (faculty-led and peer-to-peer) and educational programming process within the space. Further, Intel Corporation committed to invest funds to create a formal apprentice program for undergraduate students to serve as paid mentors within the facility to broaden student participation through peer-to-peer engagement. Following a formal application process, which required letters of support from faculty, apprentices where selected. The selected individuals include students from various engineering departments, marketing, and art/graphic design. Selected apprentices underwent a two-day emersion training that has been followed by weekly mentoring by the operations manager and advisory committee members.

Engagement in the space has been overwhelming among students, faculty, staff, and corporate partners. During the upcoming year, the College of Engineering is working to formalize a tiered corporate sponsorship program to sustain operations and maintenance of the space, while allowing varied levels of involvement among corporate partners. Similarly to other maker space facilities in engineering programs across the country, the Aggie Innovation Space falls under the reporting line of the associate dean for outreach and public service. This reporting structure ensures engagement across the workforce pipeline (corporate partners, faculty, staff, students) and serves to bridge the transfer of academic training with real-world application.

Using the Space

In order to ensure effective development of the space, an Advisory Committee was established to oversee development of educational programming, review equipment acquisition

needs (ensure broad application of limited financial resources), and serve as mentors to students. The committee meets monthly and is comprised of faculty from each of the engineering disciplines, the Department of Marketing, the Department of Art. The committee has helped to guide the development of relevant evaluation criteria for ABET accreditation as well as general operational use, support retention and persistence to timely graduation through engagement, and development of workforce skills critical for future employment.

A peer survey of 250 engineering students conducted by an industrial engineering student revealed that while access to 3D printing initially attracted students to the space, access to faculty and peer mentoring kept them engaged in the use of the facility.

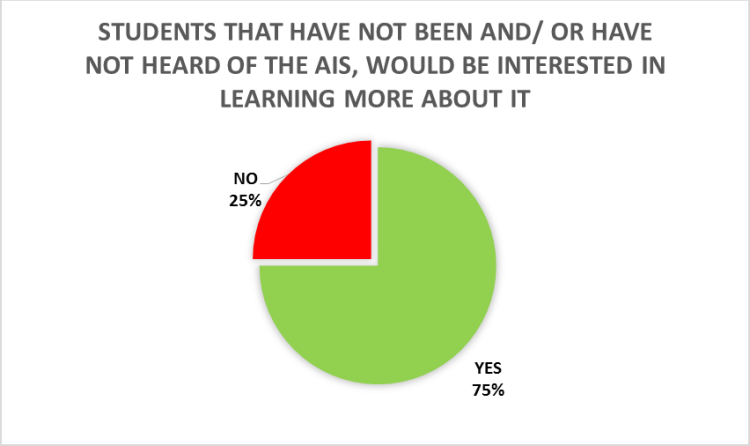
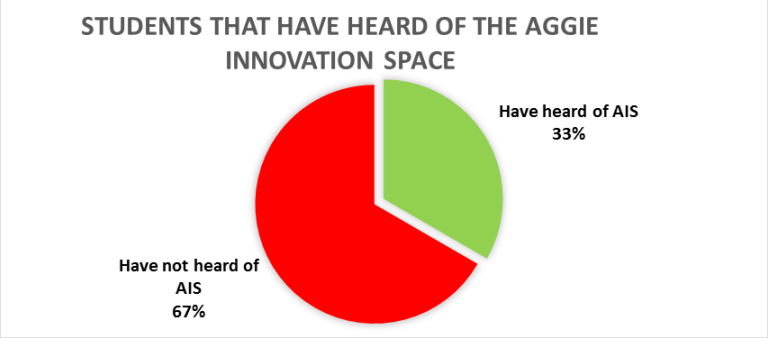


Figure 1.



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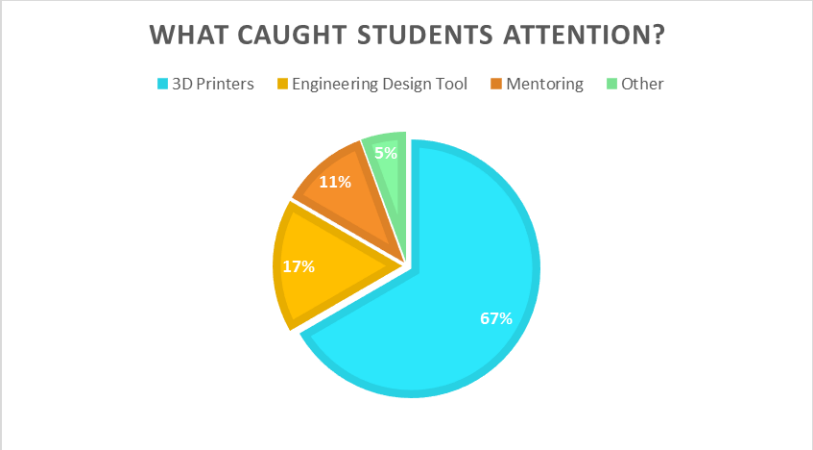

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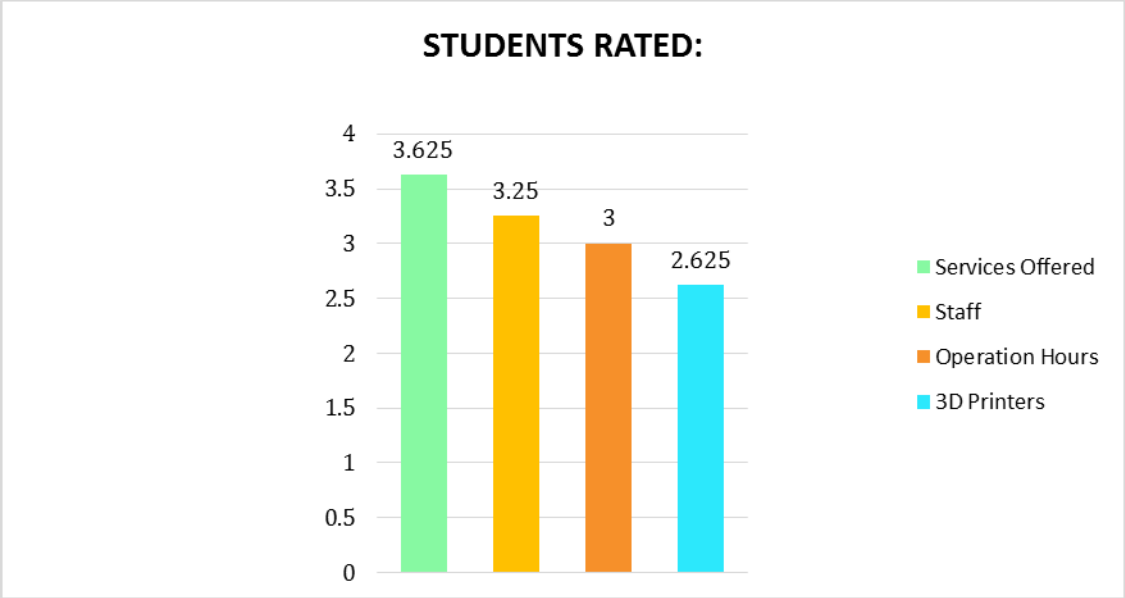

Figure 4.

The leadership team and advisory committee used the survey data to further development of relevant educational programs. A major outcome of this effort was the development of a portfolio of non-credit educational programs designed to broaden student engagement across the engineering disciplines. Two of the signature programs include Aggie Innovation Design Challenges (one-day industry-sponsored challenges open to all majors and offered on Saturdays) and Aggie Innovation Pop-Up Workshops (faculty led workshops intended to broaden and enhance student interest in niche areas – App development, 3D printing, etc.). Student interest in

these programs is high with registration (offered on-line) fully subscribed within days of announcement. Both programs are non-credit and are offered at no-cost to participating students.

The facility is now an integral component within the engineering curriculum with student involvement spanning the new Engineering 100 course to senior Capstone Design projects and new student business start-ups. As with many new initiatives, the Aggie Innovation Space faced a particular challenge in overcoming unintended consequences that resulted from engagement in the space, particularly the overuse by classes and occasional misuse by students. In an effort to broaden student participation in the realm of innovation and entrepreneurship within a product development course, the instructor had the class meet in the space during scheduled lab time so that they could take advantage of the space's available equipment and consumables. The effort was intended to expose students to the space in hopes that they would return to explore, ideate, or create new ideas outside of the classroom. Students expected to use the 3D prototype to do assignments better suited to other materials. Thus, we found we needed to adjust our management strategy such that students had appropriate expectations. Additionally, some students thought of the space as a sort of copy center where they could casually drop off their file and get a part printed by the space staff. This belief required an education effort of the proper role of the user in the space.

During the upcoming year, the Aggie Innovation Space advisory committee will be working to refine performance measures to align with ABET accreditation needs and ensure that students who utilize the facility are persisting in a timely manner through the engineering curriculum. Corporate partners will be surveyed to identify and/or confirm workforce readiness traits that can be further integrated within the space through equipment, software, and/or educational programming. Similarly to trends across the nation, the Aggie Innovation Space has become a hub for student engagement and participation has been broadened to include a diverse student demographic.

Evaluation of Outcomes

The Aggie Innovation Space has been a hugely successful endeavor for the College of Engineering. Since inception, the facility has engaged over 2500 individuals in various programmatic offerings. Programmatic engagement is delivered through a growing partnership with faculty from across the various engineering disciplines, the department of marketing, and most recently, the department of art. The table below outlines the programmatic areas that utilized the space since inception.

Program Description	Hours	Individuals
Consultations	9.75	32
Research	12.25	61
Capstone	61.25	206
Classroom	49.75	233
Organization	80.75	212
Tours	--	917
Workshops	69	687
Miscellaneous	40	165
Total	322.75	2513

Table 1.
Note: hours includes groups of students that met collectively as well as individually

Additionally, the college has provided a permanent staff manager that is assisted by nine (9) undergraduate student employees who serve as apprentices/mentors for students. As the space has grown to become an integral component within the engineering curriculum, a major focus of the advisory committee was to ensure operations and management plans were established to guide the use and maintenance of the facility. Significant accomplishments in this area include:

1. Establishment of Safety Protocols for the facility and associated equipment through a collaboration with the university Safety Office;
2. Establishment of an online scheduling program that allows students to reserve access to equipment and/or the computers;
3. Establishment of operations and management protocols to track use of the facility by program type/course/major;
4. Implemented an inventory control process to ensure effective use and purchasing of consumable materials;
5. Established guidelines for new equipment acquisition to ensure broad impact and high use by students;
6. Established two signature programmatic areas of focus
    a. Aggie Innovation Design Challenges: corporate sponsored 1-day design challenges that foster multi-disciplinary student involvement and are supported by a faculty mentor;
    b. Aggie Innovation Pop-up workshops: Offered by faculty and corporate partners, these workshops to jump-start student learning into new areas and/or areas outside of their direct major. Participation in these informal workshops is through an on-line registration and are usually full to capacity within one (1) day of announcement;

As a member of the first cohort of the NSF funded Pathways to Innovation program, led by the Epicenter at Stanford University and VentureWell, New Mexico State has been effective in leveraging external academic and industry partners from across the country to advance program offerings within the facility and work towards a plan for long-term sustainability. Further, the development of public-private partnerships ensure relevance across the curriculum towards student career readiness.

During the upcoming year, the leadership team will be focusing on the development of critical assessment tools to ensure that the space is meetings its intended goals of bridging the gap between classroom and real-world through hands-on engagement.

Conclusion

Since inception, the Aggie Innovation Space at New Mexico State University has contributed to student retention and persistence by fostering innovation and entrepreneurship across the engineering curriculum, engaged corporate partnerships to ensure transferability of knowledge gained within the undergraduate curriculum to real-world application, and has established a network of collaborations across the academic institution. The space has become a bridge between the academia and industry and, collectively, is contributing to the development of broad skillsets that go beyond the engineering curriculum (teamwork, creativity, innovation, collaboration, critical thinking, project management, and systems engineering).

The creation of the space has also re-energized faculty by engaging them in a student-centric collaborative effort that is that enhances engineering education without being encumbered by bureaucratic processes. Over the next year, the leadership team will focus efforts on development of a sustainable public-private sponsorship model that expands the number of design challenges offered per semester, the advisory committee will focus on expanding pop-up workshop offerings, and student apprentices will focus on broadening student use of the facility among their respective peer networks.

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