Building an Entrepreneurial and Innovative Culture in a University Makerspace

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Abstract
This paper reports on the first nine months of a new makerspace, with a focus on student perception of the space and the development of a community of practice. A mixed method approach – a survey, in situ observations, and interviews – was used to assess the space. Staff, faculty, and student involvement are reported. Student led training sessions and workshops, with varying levels of participation, are documented to develop best practices. Qualitative and quantitative data show that a true community of practice has yet to emerge, but many elements are present in the space. First semester attendance indicates that over half the population of the school of engineering uses the space and diversity of use is growing. Integration into the curriculum of several departments is planned as the space will grow into a resource to supplement engineering design education. An iterative approach was used for the design of the space, and this approach is continued as the community and culture of the makerspace develops.

Introduction
Universities in the United States and worldwide are investing heavily in the implementation of makerspaces as a key component to developing a mindset of innovation among students, enhancing their learning experience, in particular when it comes to engineering design skills, and promoting interdisciplinary collaboration. The idea of a university innovation space is quite recent, with the first one dating back to MIT’s makerspace around 2001 (Barrett et al., 2015). While makerspaces are appearing in many universities and engineering schools across the country, there is still very little empirical assessment of the spaces. In particular, while there is an acknowledgment of the importance of community and culture in the success of these spaces (Sheridan et al. 2013), the understanding of how to nurture a sense of community and a culture of innovation and entrepreneurship in higher education makerspaces is scant. This paper offers the unique case of the first nine months of a makerspace created by the NYU Tandon School of Engineering to foster a culture of innovation and entrepreneurship among students and an analysis of the community within the space.

The aim of the new makerspace was to encourage innovation and entrepreneurship by engaging students in both formal and informal multidisciplinary design projects. In the long term, the goal is to integrate the space into all levels of the engineering curriculum and encourage project-based learning. The university has a strong entrepreneurial center with ongoing programs as well as several incubators. The new space was designed to supplement the current innovation and entrepreneurship options available to students and student startups by providing prototyping equipment. A mixed method approach (a survey combined with ethnographic observations and
interviews) was used to analyze student use and perception of the new space. Of particular interest was exploring what resources, training, and mindsets are needed to grow a community that previous research has shown to be central to the success of makerspaces.

Equipment training and workshops focusing on design skills and innovation methods were created to support student engagement in the space, and student organizations are encouraged to use the space for club events and workshops on design, prototyping, and engineering discipline specific skills and tools. Participation and interest in fall 2016 and spring 2017 workshops were monitored to assess which topics and types foster use and community within the makerspace. A selection of these workshops are documented and shared in the paper for use by others in the makerspace community. A qualitative study of the space was conducted by the second author and a graduate student. Observations and interviews were held to assess the community of practice within the space. Additionally, a survey was emailed to all university students who had visited the space during the fall semester 2016. A follow up survey will be sent at the end of spring semester 2017. The survey, attached in the appendix, asked how students learned of the space, how they use the space, if they use the equipment, and how well the space satisfies several education and design goals. The researchers hope to compare the results from the surveys to improve the space, training, and workshops, and to stimulate future use. The qualitative observations paired with survey and use data represent a unique approach to the assessment of makerspaces that allows us to develop a rich understanding of the perceptions and uses of the space.

Building upon the literature on spaces, collaboration and innovation and the literature on community of practice, this paper presents findings about the emerging community in the space as well as the ongoing efforts made by the makerspace team to foster a sense of community and a culture of innovation and practice. Future work will build on this research to assess how the community of practice supports and reinforces engineering design education.

**Literature Review**

*Conditions for successful collaborative spaces*

The role of spaces in promoting innovation and collaboration has been studied by organizational scholars. Studies in this field have investigated how workplace design can promote learning, improve performance, support collaboration, and boost innovation (Allen, 1977; Fayard and Weeks, 2007; 2011; Kristensen, 2004; Moultrie et al., 2007). They assume that spaces’ physical and symbolic dimensions can influence behaviors (Davis, 1984; Fayard and Weeks, 2007; Elsbach, 2003) and an organization’s culture (McElroy & Morrow, 2010). However, there is also an understanding that such an influence is not a causal relation and can only be designed, with the assumptions that design does not end with the space created, but with how users interpret and use the space (Waber, Magnolfi & Lindsay, 2014; Fayard and Weeks, 2007, 2011). For example, Fayard and Weeks (2007, 2011) argue that while there are three main affordances — proximity, privacy, and permission — that support interactions in a space, finding the right balance among them is crucial because “a lopsided distribution is more likely to inhibit than promote beneficial interactions” (Fayard and Weeks, 2011, p.110). In particular, Fayard and Weeks (2011) stress
that people always interpret what are the appropriate behaviors in a space (e.g., in a library people tend to be silent or speak in a low voice) and that these interpretations often reflect an organization’s culture.

The role of culture is also highlighted in research on makerspaces, especially through the sense of community makerspaces promote and nurture: “Participants often refer to the space as feeling like a family or group of friends” (Sheridan et al., 2014, p. 528). Makerspaces support or generate a community of practice where members share knowledge, experiment, and work together on innovative projects. Studies (Forest et al., 2014; Carlson & Sullivan, 2006) indicate that students and faculty use these spaces to learn, build, and hear feedback from other users with similar interests. Martin (2015) emphasizes the importance of community and culture in being able to design makerspaces that truly foster flexible and innovative ways of thinking.

Studies of makerspaces have recognized the importance of community for nurturing successful makerspaces, sometime referring to the concept of community of practice (Sheridan et al. 2014), but they tend to focus on the learning dimension of communities of practice. While this is definitely an important component of makerspaces, especially in universities, the concept of community of practice can also shed light on the conditions to nurture lively communities that support multidisciplinary collaborations and learning.

**Situated learning by participation to a community of practice**

The situated learning perspective proposed by Lave and Wenger (Lave, 1991; Lave & Wenger, 1991) expands experiential learning approaches because it emphasizes the social component of learning, described as “an integral, inseparable aspect of social practice” (Lave & Wenger, 1991, p. 31). It reconceives learning as a sociocultural practice whereby students learn through practice and ongoing interactions with other students, faculty members, or professionals who have more expertise. Situated learning entails legitimate participation to a specific community of practice defined as a group of people “that have been practicing together long enough to develop into a cohesive community with relationship of mutually shared understanding” (Lave & Wenger, 1991).

Learning is always situated in the context of social interactions within a community, whose members engage in a shared domain of interest that defines their identity (Lave & Wenger, 1991). The domain of interest defines the shared competencies that differentiate members from other people, and because of their shared domain of domain, participants undertake activities and discussions that allow them to learn from each other, build relations, and form a community. New members start engaging with the community as apprentices through peripheral participation and they eventually gain full membership in the community as they participate more actively to various activities and hone their skills.

The situated learning perspective suggests that learning occurs by engaging with the community of practice by observing experts and through practice and continuous feedback both formal and informal. For example, the Yucatan Mayan midwives in Mexico studied by Lave and Wenger (1991) become midwives through apprenticeship believed to be quite informal. By attentively observing ‘master’ midwives, young women learn midwifery, gradually taking on the duties of maternal comfort, prenatal massage, and, eventually, delivery. While knowledge might be learned from books, it can also involve observations, experimentation, and ongoing feedback that is neither explicit nor articulated. Lave and Wenger (1991, p. 29) summarize what they call the
process of learning through legitimate peripheral participation as follows:

Learners inevitably participate in communities of practitioners and . . . the mastery of knowledge and skill requires newcomers to move toward full participation in the sociocultural practices of a community. ‘Legitimate peripheral participation’ provides a way to speak about the relations between newcomers and old-timers, and about activities, identities, artifacts, and communities of knowledge and practice. A person’s intentions to learn are engaged and the meaning of learning is configured through the process of becoming a full participant in a socio-cultural practice. This social process, includes, indeed it subsumes, the learning of knowledgeable skills.

By shifting the focus of learning from the individual cognitive development, to learning as a sociocultural practice, the situated learning perspective provides us a useful lens to understand how maker spaces might support the development of an innovative and entrepreneurial students. It also provides a relevant model to design a community of practice that can allow newcomers to engage in peripheral participation and eventually become core members of the community. It provides us with a process as well as a number of roles (core members, experts, facilitators, etc.) that have strong analytical leverage and practical implications for researchers, designers and managers of makerspaces.

Method

Research setting: structure of faculty, staff, and student support

Before the construction and opening of the makerspace, there existed a student run space dedicated to ideation and collaboration called the Greenhouse. This space was supported by a faculty member and several student employees, who helped to host, promote, and lead student workshops on prototyping. Student needs for prototyping equipment within this space was a driving force behind the creation of the makerspace. The layout of the new makerspace is shown in Figure 1, and the Greenhouse now exists within the upper left quadrant of the space. The new Greenhouse includes an 80” touchscreen (highlighted in green), movable tables, chairs, and whiteboards, as well as fixed whiteboards, cork boards, and open storage with light prototyping materials. The previous Greenhouse created a scaffolding of community and student events that is crucial to the structure of the makerspace today.

Two staff positions run the operations of the makerspace: a manager and assistant manager. Primary responsibilities of the manager include operations, budget, payroll, hiring, policy and program development, outreach, and assessment of the space. Outreach programs include partnership with the school’s K-12 STEM education center, student affairs, and enrollment management. The manager also works closely with university development and marketing and communication for support and promotion. The assistant manager works the second shift in the space (3PM – 11PM) and primary responsibilities include supervision and training of student workers, machine maintenance, and tracking of consumables. There is a makerspace faculty advisory committee made up of the manager and four faculty members. One of the members is the Greenhouse supervising faculty member, one is the associate dean of undergraduate and graduate academics, and one each is from the mechanical and electrical (head of the committee)
departments. The head of the committee, along with the Greenhouse supervising faculty member, work weekly in the space to meet with student groups and participate in workshops.

In addition to full-time professional staff, the space employs 22 undergraduate and 4 graduate students. Two of the graduate students are employed through the Greenhouse area (called “Greenhouse guardians”) and two through the general makerspace. All introductory training is conducted by students. This includes safety, 3D printers, laser cutters, small CNC, soldering, and electrical bench test equipment. A few additional training sessions are offered by full-time staff currently, but will be led by students in the future as they are trained and become more comfortable with the equipment.

A trained user database and check out program has been developed by a current student worker who is majoring in computer science. The low cost system, called “makerspace central,” uses a standard bar code scanner to read the bar code number on student IDs. This is not linked to the general university student database; the database was built out by students manually entering student information as they come in to the space and are checked off for training. Throughout the fall semester, additional features were added to keep track and log checked out items and tools, user accounts for staff and students, and easier tracking of trained user numbers.

The space is open 9AM – 11PM during the week, and 12PM – 6PM on the weekend. There are typically three undergraduate and 1-2 graduate students working during the busiest times of the day 11AM – 9PM. The student workers meet with the staff members once a month to go over new policies, make suggestions, and review past and upcoming workshops. Over the winter break, student workers were encouraged to take on a technical project to enhance their skills. Something that would either be displayed in the space or would help other students who are using the space.
Workshops

As seen in Table 1, many of the workshops were hosted by the Greenhouse and arranged through industry connections maintained by the Greenhouse guardians. Some events happened in the makerspace’s event space, which can seat up to 110, but most were held inside the makerspace itself. In addition, most of the events were only open to university students; a few workshops were open to the community as well. Some workshops taught technical and prototyping skills, while some workshops were completely non-technical and focused on skills such as resume building or networking.

The Arduino Play Time series was the most successful student led workshop series. It serves as an introduction to Arduino and sensors for those who might not have as much experience, while still being open-ended if students wanted to experiment. Arduino kits are owned and maintained by the Greenhouse guardians, and include an Arduino UNO, jumper wires, a breadboard, and an assortment of other components: potentiometer, numeric keypad, joystick, resistors and capacitors, LEDs, battery pack holder, ultrasonic sensor, small DC and stepper motors, pushbuttons. Not all kits have the same parts, and some sensors have been lost or taken. Students work in teams to learn and setup basic circuits and Arduino code.

Table 1: Fall 2016 Workshops

<table>
<thead>
<tr>
<th>Title</th>
<th>Sponsor/Host</th>
<th>Number of Attendees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prototyping Showcase</td>
<td>Greenhouse and university entrepreneurial institute</td>
<td>38</td>
</tr>
<tr>
<td>Arduino Play Time Series</td>
<td>Greenhouse and student club</td>
<td>57</td>
</tr>
<tr>
<td>Creation Hour</td>
<td>Student club</td>
<td>14</td>
</tr>
<tr>
<td>Rapid Prototyping</td>
<td>Greenhouse</td>
<td>9</td>
</tr>
<tr>
<td>Design Thinking</td>
<td>Greenhouse and student club</td>
<td>27</td>
</tr>
<tr>
<td>Story Telling</td>
<td>Greenhouse</td>
<td>16</td>
</tr>
<tr>
<td>Hacking Waste</td>
<td>Greenhouse</td>
<td>8</td>
</tr>
<tr>
<td>3D Printing Workshop Series</td>
<td>Greenhouse</td>
<td>51</td>
</tr>
<tr>
<td>Ideation Framework</td>
<td>Greenhouse</td>
<td>21</td>
</tr>
<tr>
<td>Halloween Costume Series</td>
<td>Makerspace</td>
<td>16</td>
</tr>
<tr>
<td>Holiday Gifts</td>
<td>Makerspace</td>
<td>15</td>
</tr>
<tr>
<td>EmPower Hour</td>
<td>Student Affairs</td>
<td>Approx. 40</td>
</tr>
<tr>
<td>Girls Talk Tech</td>
<td>Academic Services</td>
<td>Approx. 100</td>
</tr>
<tr>
<td>Soldering</td>
<td>Student club, professional society</td>
<td>16</td>
</tr>
<tr>
<td>Build Your Own Arduino Series</td>
<td>Student club</td>
<td>10</td>
</tr>
<tr>
<td>Intellectual Property</td>
<td>Student professional society</td>
<td>Approx. 25</td>
</tr>
<tr>
<td>Networking, dinners</td>
<td>Student professional societies</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Data collection and analysis

A mixed method approach was used to assess the first sixth months of makerspace use: a survey with qualitative observations and in situ interviews with users in the space. The survey questions
are shown in the Appendix. The focus of the questions was to assess student perception of the space by academic year, major, and gender.

Qualitative data

In order to understand everyday practices in the space and develop a deeper understanding of usages and interactions, a qualitative approach (Becker, 1998; Glaser and Strauss, 1977) was embraced. Observations were collected (about one hundred eighty hours over the fall and spring semesters) and complemented with interviews (ethnographic and in situ). Starting from the opening of the makerspace, a graduate research assistant spent an average of ten hours in the space each week during the fall semester and an average of five hours during the spring. Her observations were designed so that they would cover all days and times in the week. She developed copious notes that were regularly discussed (every other week) with the second author. The original aim of these observations was very broad: understand the uses and practices by different communities using the space. As the research unfolded, the observations became more focused on the type of activities (solo vs. group; class work vs. extra-curricular; etc.) and the types of behaviors (collaborating, helping each other, etc.) and where they occurred in the space (active vs. inactive zones; patterns of use, e.g.). During the spring semester, the research assistant did short in situ interviews (on average ten minutes) with the users in the space in order to elicit some interpretations and clarify questions that arose during the interpretative process with the second author. The research assistant conducted nineteen open-ended interviews (Spradley, 1979). At the beginning of the project, in order to understand the official motivations for the design of the space, she conducted interviews—three with members of the administration and four with faculty members who were involved in the design of the makerspace (N=7). She also interviewed students (N=12): four students who participated in insights session with the architects and some of the members of the makerspace committee, three graduate students working for the makerspace, two frequent users (one undergraduate and one graduate) of the makerspace and three members of a student club with a focus on robotics. This club, which has a long history within the school, has its own prototyping resources and space. The second author was involved in the design process and took copious notes on the process. After the space opened, the second author spent on average 2-3 hours per week in the makerspace and used her observations to inform the interpretation of the research assistant’s notes. The research assistant and second author then analyzed in parallel the notes from the observations and interviews to unveil emergent themes to complement the survey results and to define research foci to explore further in the spring semester.

Quantitative data

The survey was developed by the two authors informed by preliminary observations in the space. Several of the questions were adapted from the instrument developed by Forest et al (2014), specifically the statements on how well the Invention Studio served as a cultural hub, welcomed all types of projects, and encouraged collaboration. Additionally, the survey included questions on amount of usage, what types of projects were done in the space, and what types of equipment or tools were used.
The survey was created in Qualtrics to be mobile friendly and easily accessible. There were ten questions, with the seventh broken out into seven Likert style statements. The survey also included one open-ended response: “In your opinion, what would make the MakerSpace better?” All questions are shown in Appendix A. The survey was sent out to students in December, 2016 via email to over 2,200 students who had swiped in to the space since it had opened; 201 responses were recorded.

Analysis

Student involvement

The Tandon School of Engineering enrollment is about 5,000, with roughly half undergraduate. The makerspace is open to all schools of the university, but the majority of users are from Tandon, with 2025 student users as of December 2016 (total student users was 2200). Figure 2 shows the number of users in the training log system and the number of users who have attended certain training sessions. Safety orientation is required before use of the 3D printers and attending other training sessions. It is offered every day. However, numbers for other sessions drop off sharply, and the goal is to train many more users on the other machines and add training session types. All training is led by students, but not all TAs have completed Othermill and solder training.

![Figure 2: Screenshot of Makerspace Central Training Statistics](image)

The first-year engineering program includes a course, “Introduction to Engineering and Design,” which all engineering majors must take. All students enrolled in fall semester were required to attend the safety orientation to the makerspace as part of their fourth week lab. That will be continued this semester. So, all first-year engineering students will be introduced to the makerspace by the end of the year as part of their standard curriculum.

Workshops

Some workshops were more successful than others. This was due in part to promotion and timing, and in part due to the topic or sponsoring organization. As the semester progressed, the makerspace TAs and Greenhouse guardians became more familiar with the promotional process:
creating a poster, posting a digital copy on the makerspace website and/or sharing with interested student groups, posting hard copies on student notice boards and makerspace walls, and creating an Eventbrite. Previous workshops held in the Greenhouse before the makerspace opened had the most success with student turnout when an Eventbrite or similar ticketing system was used, as a form of accountability or commitment.

Arduino Play Time, the most successful workshop series was run by a student club, Patent Pending, that had been active for several years. This workshop emerged from requests from students who were going to introductory workshops run by Patent Pending and who wanted an opportunity to hone their skills. The Design Thinking and Rapid Prototyping workshops were also run by a student club, Design for America NYU, that had been active for several years with the support from a faculty member. In both cases, the clubs had a strong membership base, had existed for several years, and were willing to experiment and iterate with the workshop format and responded to other students’ expression of interest or needs. Both clubs worked hard to communicate effectively with others and bring core members to the events, while also providing introductory level workshops that were accessible to new members.

Workshops that were not successful, like Creation Hour, did not have a strong community or interest to drive attendance. Creation Hour was put on by the student led NYU Entrepreneurship and Innovation Association (EIA) and featured open weekly meetings for students to discuss and work on projects. While the idea was good, it was too broad (“come work on a project”) for students to respond to. The club also did not have a large or supportive membership base; only a few students showed up to the workshops. Instead of adapting or tuning the focus of the workshops, after two meetings, the club gave up and cancelled Creation Hour.

Observations from the field

Findings from the qualitative study show that while the space is used by some student teams and student clubs, many students in the space work either individually or on class projects that do not require the making facility. Students often use the 3D printers for small personal projects rather than for a class or team project. It was also found – in line with the literature on communities of practice – that the makerspace community is composed of four main group of users: the student TAs, who are a very closed group; a small group of core expert users (15 to 20 members, mostly male students) who are often had prior connections with the TAs; regular users who seemed to be using the space mostly for its co-working and meeting facilities, and some infrequent users. The observations and informal conversations with other students in the space suggest that there was a strong in-group vs. out-group distinction that made it difficult for students who were not part of the TA or core users group to engage with these groups. Training sessions run by TAs did not seem to help reduce this gap as they tended to be very technical and fact oriented, presupposing a technical background. Several participants who had no technical background felt lost. It was also noticed that very few new users went to the TAs to ask for help. Even the core users, who often tended to stay together in one part of the space, making it difficult for others to feel comfortable approaching them, were seldom approached. Vice versa, there were few instances of TAs or expert users offering help to a newcomer.
The findings unveil some interesting use patterns that are planned for further exploration. For example, the architects designed an open space with a concierge desk to invite newcomers to ask for help. However, the observations and in situ interviews indicate that many users coming to the space did not feel welcome. Some students explained that they did not step in because they felt unwelcome and were not sure where to go. Several noted that they did not feel like asking a question to the TAs behind the counter because they seemed busy with their work or in group conversations; the counter appearing as a barrier preventing access and interactions. Many newcomers ended up sitting in the foyer area outside of the makerspace, which has become a buffer space for students to work on their own or with friends.

The foyer area, shown in Figure 3, was also a space used by core members and TAs for informal connections, as this is where they could drink and eat (both activities forbidden in the lab space). While the foyer could have been an interesting space where boundaries between different groups could have blurred, the observations show very little interactions between the different types of users. In the spring semester, further investigation of the use patterns by different sub-groups is planned to inspire iterations with the design of the space. The goal is to create new pathways that might increase serendipitous interactions among different sub-communities.

![Figure 3: View of Foyer from Inside Greenhouse](image)

Light prototyping was done in the spring semester to make the entrance more inviting and reduce the barriers to entry for newcomers. The entrance felt very closed off because there was a white board right on the side asking people to swipe their card. This board blocked part of the view and led people to always use an entrance path on the left of the space, attempting to lead users to the card swipe machine which was on the counter and not easily visible. In fact, several visitors mentioned that they found the board’s message and location uninviting. The first, often only, interactions with the TAs behind the counter with visitors was their asking people to swipe their cards. To make sure that people will see the board swipe, the TAs had created a pathway with stanchions. These were removed, and the card swipe was mounted on a TV stand nearby the counter, making it visible and easily accessible. Also, a group of eight colorful armchairs had originally been placed near a work table area and were blocking the way. These chairs were moved closer to the entrance, creating a more inviting entrance and a waiting-room like area. Observations of both changes were positive. Now, when entering the space, visitors have a
complete view of the space and tend to explore more. Visitors nearly always went directly to swipe their cards without having to be asked by the TAs, and initial feedback suggests the space is perceived as more open and welcoming.

Finally, the qualitative data suggest that while there are many of the elements of a community of practice (a domain of practice – making and prototyping; different member groups), the space has not been able to support the process of legitimate peripheral participation that will allow the makerspace community to become a true learning community, one that is nurturing and sustainable.

*Fall survey results*

Fall 2016 survey results are displayed below. While email announcements about the opening of the space were sent to all students in August 2016, the majority of students (58%) found out of the space by walking by. The self-reported demographics and space and equipment usage of respondents are shown in Figures 4 and 5.

![Figure 4: Survey Demographics](image-url)
Over a quarter of respondents (28%) indicated that they do not use any of the equipment in the space during their visits, and homework was the second highest reason that students came to the space with 55% of users reporting this. This is supported by the qualitative observations that many students do not use the equipment for projects. Working on personal projects was the top reason that students came to the space at 63%. As expected, 3D printers were the most used equipment with 62% of respondents indicating their use.

113 students (56%) responded to the open-ended question on the survey: “what would make the space better?” Not surprisingly, many wanted to eat or drink in the lab. 20 of the responses
included some reference to more or better training or workshops – 18% of those who replied to the question – including more introductory level training: “A general how to for everything. I know they have trainings but sometimes that doesn't feel enough for beginners.” One response also asked for video tutorials, which are being created this semester.

All responses to the Likert questions are shown in Figure 6. While the majority of students agree or strongly agree that they know who to ask for help, our qualitative findings show that many students might not feel comfortable approaching TAs for help. This question will be changed in future versions of the survey to assess whether students feel comfortable asking for help or willing to ask for help rather than whether they know who to ask. In order to truly nurture a community and support projects, students must eventually feel comfortable asking for help, supplies, and feedback on their work. These community statements will be asked again in the survey sent out at the end of spring semester to assess whether student perception and use has changed.

Figure 6: Survey Total Likert Question Responses

Not surprisingly for an engineering school, 53% of the respondents to “I enjoy learning to use new machines” indicated that they strongly agree. A further analysis of that statement and “I feel confident using the equipment” are shown in Figure 7. These responses do not indicate that students are making the leap of learning to use multiple different types of machines in the space, however, as seen by the training participation numbers in Figure 1.
The self-assessment of engineering design skill improvement through the makerspace is shown in Figure 8. Some students may not have a clear understanding of “engineering design skills” and the Likert question could be better phrased or broken down into several different statements explaining design or offering examples of different types of design that students may be involved in. Students may have interpreted the statement to include any basic prototype construction
(“making something”) or tinkering in the space, rather than the standard iterative engineering design process with problem identification and research, brainstorming and solution design, creation, assessment, and revision. To better assess this in future versions of the survey, this question should include more guidance or information about design steps. It is clear that some students use the makerspace to build prototypes, but they may not be connecting that type of use to research, analysis and assessment, or revision, even though these are key components of the design process.

As courses start to include requirements to use the makerspace for course projects or homework, assessment of the space could also include questions on design tied to specific courses. As the first-year engineering design course requires students to attend a makerspace orientation and the design projects are adapted to use makerspace equipment (currently 3D printing is only part of the extra credit options for the project), students may be able to more easily connect their required design projects to use of the makerspace. Several courses in the mechanical and civil engineering, digital media, and technology management are requiring makerspace use this spring semester, with more planned in following semesters. Including a question about course use would lead to assessment of whether course integration changes perception and use of the space and equipment.

Finally, the three statements in Figure 9 attempted to relate student community and teamwork perception. As discussed, the neutral or negative responses to the community responses seem to support the qualitative analysis of limited community involvement between core users and newcomers. The data for these questions will be analyzed at the end of the semester to compare whether current and upcoming design interventions in the makerspace have changed the perception of teamwork in the space.
Figure 9: Community Questions Results
Discussion and Conclusion

While the findings suggest that the makerspace does not yet shelter a nurturing learning community of practice or support legitimate peripheral attention, they do demonstrate the presence of important elements: a strong core group; an involvement of student clubs; an increase in participation and an increased diversity in the users. These can lead to the emergence of a community that will, in time, support legitimate peripheral participation and a culture of innovation and entrepreneurship in design.

Learning from the first two semesters, there will be continued training and requirements for TAs, updated and different workshops focusing on learned, defined skills, panels bringing in industry experts and mentors, and continued support for entrepreneurial activities and projects. TAs and early adopters of the space are core users, but training sessions and workshops need to provide more introductory information and a welcoming start for newcomers. To accomplish this, design interventions are planned for the space throughout the spring semester; some have been discussed in the findings.

Swipe in data from the space has shown an increase in participation and use from women students. The demographic breakdown during the first month and half was around 26% women. This grew to 29% in the following two months. Looking at the first week of spring semester, 2017, 31% of the users who swiped in to the space were women. The goal for this semester is to increase to at least 35% of users. Comparison of survey and qualitative analysis, training numbers and qualitative assessment show that training sessions need to be improved.

Future work: experiments to develop the community of practice

This is the first year that the makerspace will support the school of engineering’s annual spring prototyping competition. The competition has grown from about $20,000 in total prizes and support to $55,000, and the focus is on a hardware prototype. There has also been a push through multiple departments to create a project-based curriculum spanning all four years of the undergraduate engineering degrees. While full integration into the curriculum of all departments is still several years away, a new junior level project-based multidisciplinary course is being created with funding from a VentureWell grant. The school has also adopted the Vertically Integrated Projects (VIP) Program started at Georgia Tech. There are five current VIP courses, with a new course this semester taking full advantage of the makerspace for meeting, prototyping, and equipment. Future plans include merging some of the best practices of the Yale CEID model for design courses (Wilczynski, 2016) with more student-based and informal learnings models like the Innovation Studio at Georgia Tech (Forest, 2014) or the d-school at Stanford to create an environment that can best support engineering design education. This blended model will work best as it acknowledges the institutional constraints of new curriculum design and implementation while also providing more opportunities for experimentation and interdisciplinary collaborations across departments in the engineering school and across different schools within the university.

Through the Greenhouse in the makerspace, small prototyping grants will be offered. The awards would be $50 with a one page, simple application, and they will be offered once or twice per
month. A “needs and have” wall will be created in the space, encouraging interactions and 
exchange. Students will be invited to post if they need an additional team member, help with a 
certain aspect of their project, or even a team for a new project idea, or if they have skills or 
expertise and are looking for a project to work on. The Greenhouse guardians have emailed all 
student clubs about offering workshops inside the makerspace, encouraging new students to visit 
and use the space. Increased collaboration with student affairs, which manages all student clubs, 
will increase knowledge about the space and resources available.

The TA projects over the winter break were successful in encouraging TAs to learn new 
machines and create display projects or prototypes to improve the space. Projects for this 
semester include a Raspberry Pi Zero device to read the amount of filament in Stratasys filament 
cartridges, a live stream of the 3D printer and laser cutter areas, a new public website with a blog 
featuring projects and workshops, and devices to monitor and automatically update printer status 
on the training website. A new, better website with a blog and makerspace videos are planned for 
this semester. Videos will include an introductory overview of the space. Training videos will 
also be created for the 3D printers and laser cutters this semester, with more specific equipment 
training planned. Having videos will serve as a better refresher and standard for the training 
sessions. It may also be more accessible for students who have not entered the makerspace yet 
and prefer to learn before they visit. The blog will serve as a place for sharing stories of 
workshops and events as well as projects and teams that can inspire people to work on their own 
project, or trigger them to reach out to some of the students and teams featured on the blog.

Embracing a human-centered design perspective (Bratteteig et al. 2012), the authors believe that 
design does not stop when the space is open, but continues through the use and practices that 
emerge and the ongoing iterations that are developed in response. Hence, the design of the 
makerspace did not end with the opening of its doors in September 2016, and it is an ongoing 
iterative process, understood as a series of experiments to test assumptions and generate new 
design opportunities. Observations of the interactions and community within the makerspace will 
also be continued throughout the semester. Workshop attendance and reception will continue to 
be monitored. A survey will again be sent out at the end of the spring semester. Questions on 
community and engineering design skills will be changed to better assess student reactions. The 
ingineering design skill statement will be broken into several statements to address 
understanding of the multi-step design process. Question 5 (shown in Appendix A) could also be 
edited or supplemented to assess understanding of the design process. Through iterations of this 
research, the authors hope to document the growth of a community of practice within the 
makerspace and report on the resources, training, and mindsets necessary to grow such a 
community.

References


Appendix A

Makerspace Survey Fall 2016:

Q1 How many times during the week do you come to the MakerSpace?

- Once a week or less (1)
- 2-3 times per week (2)
- 4-5 times per week (3)
- More than 5 times per week (4)

Q2 I come to the MakerSpace for: [choose all that apply]

- Personal projects (1)
- Class projects (2)
- Student organizations (3)
- Homework (4)
- Meetings (5)
- Workshops or training (6)
- Lectures or talks (7)

Q3 What kind of equipment do you use in general? [choose all that apply]

- Soldering and electrical bench test (1)
- 3D printers (2)
- Laser cutters (3)
- Micro-CT scanner (4)
- Sewing and embroidery (5)
- Hand tools (6)
- Othermill (milling) (7)
- Prototyping tools in the GreenHouse (8)
- None (9)

Q4 How did you find out about the space?

- Email (1)
- Friend (2)
- Professor (3)
- Walking by (4)
- Class (5)
Q5 Which of these do you associate with the MakerSpace? [check all that apply]

- Innovation (1)
- Entrepreneurship (2)
- Making (3)
- Community (4)
- Prototyping (5)
- Playing (6)
- Brainstorming (7)
- Experimenting (8)
- Learning (9)
- Social (10)

Q6 In your opinion, what would make the MakerSpace better?
Q7 Statements about your use of the space

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree (1)</th>
<th>Disagree (2)</th>
<th>Neutral (3)</th>
<th>Agree (4)</th>
<th>Strongly Agree (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I enjoy learning to use new machines (1)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I come to the MakerSpace to meet people who share similar interests (2)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I come to the MakerSpace to meet people in other majors (3)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>When I come to the MakerSpace, I prefer to work alone (4)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I feel confident using the equipment in the MakerSpace (5)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Working in the MakerSpace has improved my engineering design skills (6)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I feel the MakerSpace is a welcoming environment for all types of projects (7)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I have access to the equipment I need when I come to the MakerSpace (8)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I know who to ask for help if needed (9)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

Q8 What is your academic year?

- First-year (1)
- Sophomore (2)
- Junior (3)
- Senior (4)
- Graduate (5)

Q9 What is your gender?

- Male (1)
- Female (2)
- Prefer not to say (3)
Q10 What is your major?

☐ Applied Physics (1)
☐ Biomolecular Science (2)
☐ Business and Technology Management (3)
☐ Chemical and Biomolecular Engineering (4)
☐ Civil Engineering (5)
☐ Computer Engineering (6)
☐ Computer Science and Computer Engineering (7)
☐ Computer Science (8)
☐ Construction Management (9)
☐ Electrical Engineering and Computer Management (10)
☐ Electrical Engineering (11)
☐ Integrated Digital Media (12)
☐ Mathematics (13)
☐ Mechanical Engineering (14)
☐ Physics and Mathematics (15)
☐ Science and Technology Studies (16)
☐ Sustainable Urban Environments (17)
☐ Bioinformatics (18)
☐ Environmental Engineering (19)
☐ Biomedical Engineering (20)
☐ Biotechnology (21)
☐ Biotechnology and Entrepreneurship (22)
☐ Chemistry (23)
☐ Financial Engineering (24)
☐ Industrial Engineering (25)
☐ Mechatronics and Robotics (26)
☐ Translational Surface Engineering (27)
☐ Transportation Management (28)
☐ Transportation Planning and Engineering (29)
☐ Other (30)

Q11 If you choose other, please enter your major: