Assessment of a University Makerspace Using a Quantitative and Qualitative Student Survey

Mr. Lee Allen Dosse, University of Pittsburgh

Lee A. Dosse is a Ph.D. student studying engineering education at the University of Pittsburgh. He is interested in how makerspaces can positively contribute to the education of engineering students, and has a keen interest in the university's XProjects program as an engineering education tool.

Irene B. Mena, University of Pittsburgh

Irene B. Mena has a B.S. and M.S. in industrial engineering, and a Ph.D. in engineering education. Her research interests include first-year engineering and graduate student professional development.

Prof. William W. Clark, University of Pittsburgh

Dr. William W. Clark is a Professor of Mechanical Engineering and Materials Science at the University of Pittsburgh, and founder of the tech startup Diamond Kinetics. He is an active researcher and teacher in the field of dynamic systems and control with emphasis on mechatronics, sensing, embedded control, and data-driven systems. He is currently director of the Innovation, Product Design, and Entrepreneurship program in the Swanson School of Engineering at Pitt, and is interested in growing a culture of innovation and entrepreneurship among engineering students.

Assessment of a University Makerspace Using a Quantitative and Qualitative Student Survey

Abstract

This research paper focuses on the assessment of a makerspace at the University of Pittsburgh through the use of a student survey designed to answer whether the space is achieving its goals and how it is impacting users. As the rate of technological and societal change continues to increase, further emphasis is being placed on training skilled engineers, and calls for changes in engineering education to better prepare engineers for the future have been made.

One approach institutions have taken towards achieving this is through the use of makerspaces. Anecdotal and indirect evidence support the use of these facilities to improve engineering skills in students.

The makerspace of interest was built two years ago employing many of the best practices used at other institutions, and is also an integral part of a larger program at the university. To date, minimal data has been collected concerning the efficacy of the makerspace.

To assess the makerspace, an anonymous survey comprised of Likert scale items, open-ended questions, and other quantitative questions was distributed electronically to both undergraduate and graduate engineering students. It asked students to rate statements about the makerspace related to its mission, and to rate statements about how using the space has improved different aspects of themselves.

The results of the survey showed that the makerspace appears to be achieving its goals and is functioning as part of the university's efforts to increase student innovation and entrepreneurship. It showed that students feel using the makerspace has had positive effects on them, especially their creative thinking and ability to work on a team. It also revealed what aspects of the facility could potentially be improved. This evaluation contributes to the increasing body of knowledge on makerspace practices and potential impact on students.

Introduction

The start of the 21st century brought with it a call for reforms and improvements in engineering education. It was recognized by organizations like the National Academy of Engineering that the engineer of the future would not only require enhanced analytical skills and design ability, but also a mastery of other skills, such as communication and teamwork [1], [2]. In addition, it has also been recognized that there is a need for increased emphasis on innovation and entrepreneurship at the university level [3].

As colleges and universities strive to meet these challenges, makerspaces have become increasingly common across the U.S. and abroad, having been identified as a potential means of achieving these goals [4]. Makerspaces are places where users can gather to work on various projects, either individually or in groups. These spaces can vary considerably between institutions in terms of equipment, user access, and operation [5]. While many configurations

exist, most typically have different tools and machines for prototyping and manufacturing, ranging from simple hand-tools like screwdrivers to high-tech 3D printers. These facilities allow for plenty of hands-on experience and bring together diverse groups of people, promoting student interaction and the exchange of ideas, where the benefits of physical modeling and communities of practice are well-documented [6].

The literature addressing the impact of makerspaces on engineering students continues to grow and is an active area of research. Studies have shown these facilities have a number of positive effects on users. Early exposure to hands-on, team-based design work has been shown to improve retention rates for engineering students [7]. Surveys have shown users feel these spaces had a positive impact on many attributes vital to engineering, such as design and analytical abilities, design self-efficacy, communication skills, management skills, and working effectively as a team [6], [8], [9], [10].

About the Makerspace

The makerspace being studied is relatively new, having only opened in 2016. The space is approximately 1700 sq. ft. and is divided into several distinct areas. The front of the room close to the entrance has a dual-function whiteboard/table, a couch, and a 60" monitor. It is setup for meetings, training for new users, lectures, planning, and if desired, relaxing. The middle of the room has several large tables and is designed for testing out ideas and assembling small to medium sized projects. The area can also be used for design work and studying. The back section along the far wall has several work stations for using tools including a station for soldering and circuit construction and testing.

The facility is open Monday through Friday, 10 am to 10 pm, and currently employs 21 student mentors. These student mentors are a cornerstone of the makerspace. The space is led and operated by them, and the predecessor group to the mentors even assisted in designing the layout of the facility. The mentors are in charge of the space during their shifts and are there to assist users as needed, answering questions as well as teaching them how to use different tools and advising them on their work. All university students are welcome in the space; however, collected data indicates very few students outside of engineering have yet to step foot in the facility.

While they are not physically linked, other rooms have since come online as part of the makerspace system at the university. These include "the Treehouse", a digital fabrication space with 3D routers and laser cutters, and a digital media lab. With these additional spaces coming online as part of a larger system, the popularity of the makerspace itself has increased over time, registering around 500 unique users in the space out of the nearly 3,900 undergraduate and graduate engineering students enrolled at the university over the course of the 2017 – 2018 academic year. The makerspace is primarily focused on ideation, rapid design iteration and prototyping. The space hosts three 3-D printers (Ultimaker model 3 extended), sewing machine, vinyl cutter, T-shirt press, and an electronics workbench, but also has simpler modeling items such as wood, clay, K'nex, toothpicks, and various glues and fabrics. Something that makes the makerspace unique among many other university makerspaces is its X-Projects program. The

program seeks to encourage cooperation between engineering students and industry, which will be the subject of future research.

Having a clearly defined mission is listed among best practices for makerspaces [4], and the space being studied is no exception. The makerspace was constructed as part of the University of Pittsburgh's Innovation, Product Design, and Entrepreneurship program, and as such carries the same mission, which is:

"To develop a culture in which students learn to create, cultivate, and launch impactful ideas."

The purpose of the study was to answer two questions: 1) Has the makerspace been achieving its mission? and 2) What effects has the makerspace been having on its users? The answers to these questions will contribute to the growing body of literature on makerspaces in higher education.

Methodology

The study made use of an anonymous, electronic survey comprised of quantitative and qualitative questions, and was distributed to all undergraduate and graduate engineering students, through Qualtrics, the University-approved platform. The survey gathered information on student demographics as well as information about how students used the makerspace, such as the amount of time per week users averaged and how that time was spent. The survey also had two 5-point Likert scale questions that ranged from "strongly disagree" to "strongly agree". These two Likert scale questions allowed respondents to evaluate if the makerspace was meeting its stated goals and what effects they felt using the space was having on them.

The survey had three qualitative questions, two of which were focused on the makerspace while the other was concerned with its users. The two makerspace questions asked respondents what they felt the makerspace does well and what they felt could be improved. The question about the users asked what skills or abilities they felt were improved by the makerspace and why. The question is similar to the one using a Likert scale; however, the open-ended version of the question came before the closed one to reduce the influence of the pre-selected skills and abilities on the students' written answers. The responses to these questions were analyzed using a coding scheme following steps recommended by Creswell [11]. The responses were first read through to get a general sense of the data, and were coded during further readings. The codes were then condensed into themes. No predetermined themes were actively searched for, and the final themes uncovered emerged from the data itself. The qualitative questions were used to collect additional information on the makerspace and its users as well as to corroborate the scores found in the Likert scale questions, and are not meant to be used to develop or validate hypotheses or theory.

This survey is meant to be used to acquire a preliminary understanding of the makerspace program and to guide future research. As it has not been tested for validity or reliability, the conclusions derived from the survey should be interpreted carefully.

Results & Discussion

The survey was released at the beginning of the fall 2018 semester and remained open for one month. A total of 317 responses were collected out of a total of approximately 3,900 engineering students, yielding a response rate of around 8%. While not as high as desired, it is important to note that the survey split respondents into two separate groups – those who have used the makerspace and those who have not. This was done as it was desired to understand why students may not be using the space. Of this total, 117 had spent time in the facility, while 200 had not. Out of the nearly 500 unique users registered in the space, 117 answered the survey, representing a response rate of around 23% for this group, which is significantly higher than the general response rate. The following sections concern the users of the makerspace.

Demographics

The collected student demographic data showed that juniors and seniors were the primary users, comprising 68% of total users, with freshmen and sophomores combined being only 26%. This is not unexpected as there exists minimal integration between freshman curriculum and the makerspace. There is some integration at the sophomore level and beyond, but the majority of courses do not make use of the facility. It is encouraging to see that 6% of users were at the graduate level. Mechanical engineering was the most common engineering major among users, comprising 45% of students, followed by electrical engineering with 15%. The remaining majors are represented relatively equally in the space. The vast majority of users identify as white and male with 81% and 70% of users, respectively. Given previous research and the demographics of the university, this is not surprising. That being said, women and minority students are still underrepresented within the space, and efforts have and are continuing to be made to improve the situation.

Makerspace Use

In addition to basic demographic data, it was desirable to know other details about the students using the makerspace. One such detail was how long students had been using the facility. This can be seen below in figure 1.

It was found that 40% of respondents had used the space for only one semester, 30% had used it for two semesters, 24% had used it for 3-4 semesters, and 6% had used it for 5-6 semesters.

Another question asked was how many hours per week users spent in the space. Their responses are detailed in figure 2.

On average, most users do not spend large amounts of time in the facility, with 46% of those surveyed saying they spend less than 1 hour per week and another 38% saying they spend 1 – 5 hours per week there. Another 5% spend 6 – 10 hours per week, while another 6% said they averaged 11 – 15 hours a week. Finally, 5% of students said they spent over 15 hours per week in the space – a fairly significant amount of time. A notable trend appears in the data when looking at the number of hours per week vs the number of semesters a student has been using the

makerspace, which is that as the number of semesters of use increases, the average number of hours spent per week in the space also increases.

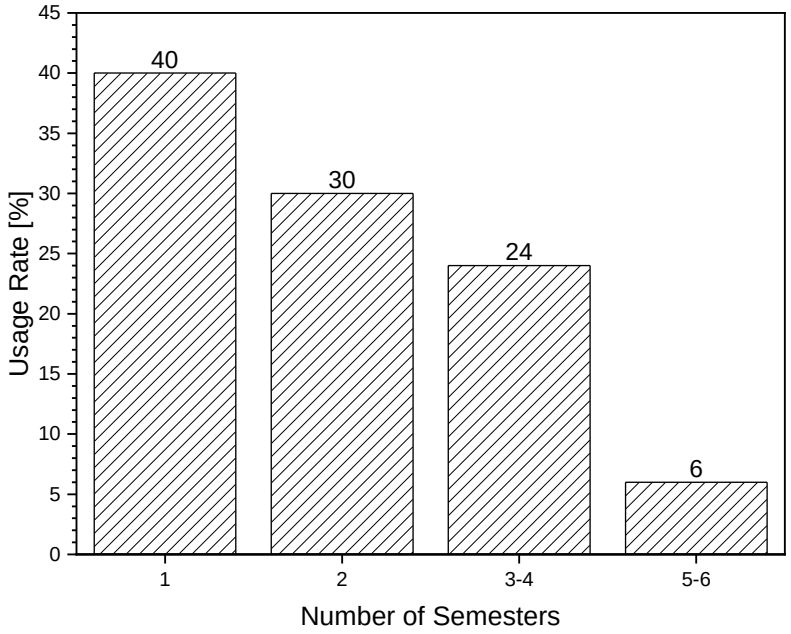

Figure 1. Percentage of students who have spent time in the makerspace as measured by semesters.

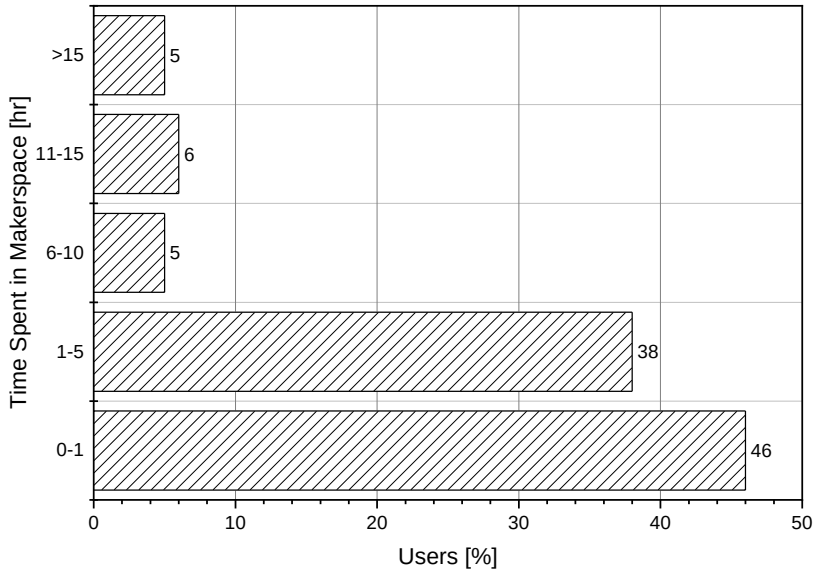

Figure 2. Percentage of users using the makerspace as measured by hours per week.

The survey also asked students to express what percentage of their time in the makerspace they spend performing different activities. This can be seen in figure 3.

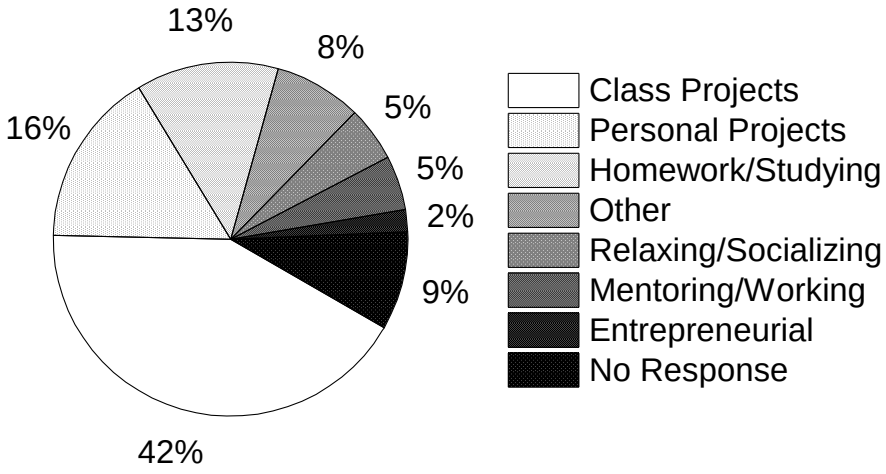

Figure 3. Breakdown of how users spent their time in the makerspace.

Overall, users spent 42% of their time working on class projects, followed by personal projects and homework/studying occupying 16% and 13% of their time, respectively. The remaining time was spent on other (8%), relaxing/socializing (5%), mentoring/working for the space (5%) and finally entrepreneurial/start-up activities (2%). As with the number of semesters of use vs. hours per week, trends appear in the data depending on how long students have been making use of the space. As the number of semesters of use increases, students spend significantly less time working on class projects (57% of time for one semester users vs. 4% for 5 – 6 semester users). As the time spent on class projects decreased, the time spent on personal projects increased for one semester users from 12% to 40% of 5 – 6 semester users. Homework/Studying, Relaxing/Socializing, and Other all increased slightly with increasing time spent using the makerspace. The time spent working as a mentor increased from 0% to 20%, which makes sense since students who have continued to use the facility over time are more likely to become makerspace mentors. A disappointing result is the amount of time spent working on entrepreneurial and start-up endeavors. The university's Innovation, Product Design, and Entrepreneurship program is still in its infancy; however, and it is expected these numbers will increase as more students become involved in the program.

Makerspace Assessment

One of the primary goals of the survey was to evaluate if the makerspace was fulfilling its mission statement. This initial assessment was performed using a combination of quantitative and qualitative questions. Twelve items or goals associated with the mission statement and makerspaces in general were selected for evaluation using a 5-point Likert scale, ranging from strongly disagree (1) to strongly agree (5). The results are presented in table 1.

Table 1. Average score of n = 103 makerspace user responses to the request "Please indicate the degree to which you agree with the following statements."

Item	Description	Mean	Median
1	The Makerspace encourages innovation in engineering.	4.26	4.00
2	The Makerspace encourages entrepreneurship in engineering.	3.81	4.00
3	The Makerspace has provided me with opportunities for involvement in product development and other startup activities.	3.64	4.00
4	The Makerspace has provided me with opportunities to help other students in the facility.	3.77	4.00
5	The Makerspace has provided me with opportunities to attend workshops and other 'Maker' related events.	3.82	4.00
6	The Makerspace mentors have been knowledgeable about the Makerspace.	3.93	4.00
7	The Makerspace mentors have been available to assist me as needed.	3.78	4.00
8	Training has been readily available to learn the different machines and processes used in the Makerspace.	3.50	4.00
9	The available training has provided me with the skills needed to effectively use the Makerspace.	3.66	4.00
10	I feel comfortable working in the Makerspace.	4.13	4.00
11	Using the Makerspace has contributed to my learning.	4.08	4.00
12	I have learned new facts, concepts, or skills from other students in the Makerspace.	3.87	4.00

All of the responses are at a score of 3.50 or above, with most items ranked between 3.50 and 4.00, placing the statements around the "agree" category. The most positive items were numbers #1, #10, and #11, all of which were at 4.00 or above. These scores indicate that while the makerspace shows room for improvement, it appears to be upholding its mission statement and achieving its associated goals. This is especially true regarding #1, since encouraging innovation in engineering is one of the key objectives of the makerspace.

The open-ended question "What are some things you feel the makerspace does well?" was used to corroborate the user evaluation of the facility. This question received 63 responses, with an average length of 15 words per response. Analysis of the open-ended answers shows some support for the item scores. The most common theme appearing in a little over 50% of responses was that the makerspace provided users with a variety of tools and a good place to work. While it is good to see users appreciated the makerspace as a workshop, other themes were more interesting. Around 30% of responses noted the sense of community among users, which includes helping and teaching one another, providing support for items #10 and #11. The theme of innovation appeared in about 10% of responses, providing support for item #1. Two other themes appeared in the data, which dealt with creativity (16% of responses) and extracurricular learning (17% of responses). One user response was very approving of the university's efforts thus far:

> "A convenient place to find like-minded engineers. It feels like home. Make almost anything free of cost. Lots of resources to learn, make, discover, and innovate. I think makerspaces are awesome and I never expected I would learn so much in a very short time. I now believe that you can make anything and all you need is an idea. Normal classes are never this practical and fun and I really wish that changes soon."

The most negative items were item numbers #3, #8, and #9, with scores of 3.50, 3.64, and 3.66. Interestingly, these items all deal directly with how the makerspace is operated.

The open-ended question "What are some things you feel could be improved in the makerspace?" was also used to support the user evaluation and gather further feedback. This question received 66 responses, with an average length of 38 words per response. The themes found in the responses add some level of corroboration. The most common theme, being noted in 44% of answers, was to provide more tooling. This included both hand tools as well as machines like lathes and mills. This was somewhat surprising. It would seem most users have either forgotten or are unaware that the primary purpose of the makerspace is for low-resolution prototyping as opposed to fabricating full-size, final products. Other places at the university are specifically designed for more intensive fabrication procedures like metal working. The second most common theme concerns the student mentors. Approximately 25% of users reported some issue with them, but still scored their abilities fairly well. The two main complaints were in the performance and training of the mentors. It was noted that the mentors could be more proactive in the makerspace. Users recommended that mentors make sure to introduce themselves to anyone who enters the room, approach students more often to ask if they need assistance, and provide more encouragement for users to work on personal projects. Interestingly, both mentors and users recommended additional training for mentors on makerspace rules, tools, and programming. The third most common theme, being noted in 21% of responses, deals with the perceived formation of cliques within the makerspace, with some students feeling a disconnect between regular users and mentors. The last two themes identified issues with access to information about the space (e.g. scheduled events) and the facility itself, and with availability of training. All students must go through basic safety and orientation training before they are allowed to use the makerspace. These themes help explain the lower scores of items #3, #8, and #9. The makerspace offers many different 'Maker' events throughout the year, as well as opportunities for involvement in product development. The fact these themes appeared in the data despite the opportunities available may indicate a communication problem between staff/mentors and regular users.

Effects of the Makerspace

The second major goal of the survey was to determine what effects the makerspace was having on its users. Similar to the Makerspace Assessment, this was done using both quantitative and qualitative means. Ten engineering skills/abilities were selected based on literature (such as [1], [3], and [6]), as well as our own list of goals for users. These were evaluated using a 5-point Likert scale, ranging from "strongly disagree" (1) to "strongly agree" (5). The results are presented in table 2. Note that all responses are self-reported, and results should be interpreted carefully.

Table 2. Average score of n = 88 makerspace user responses to the request "Please indicate the degree to which you agree with the following statements. Using the makerspace has improved my: "

Item	Description	Mean	Median
1	Problem-solving skills	3.90	4.00
2	Ability to use the design process	3.99	4.00
3	Creative thinking	4.08	4.00
4	Ability to work in a team	4.03	4.00
5	Ability to act as a leader	3.69	4.00
6	Communication skills	3.73	4.00
7	Ability to manage projects	3.83	4.00
8	Performance in other courses	3.48	3.00
9	Ability to mentor or teach	3.56	4.00
10	Confidence in working as an engineer	3.99	4.00

All scores except for one are above 3.50, with most scores concentrating around the choice "agree". It was expected that the students were benefitting from using the makerspace, and the data shows the students perceive that as being true. It is interesting to see what skills or abilities the users feel they are benefiting most in. Creative thinking and the ability to work in a team were the abilities users felt the makerspace helped them improve the most, followed closely by the ability to use the design process and confidence in working as an engineer. Users felt that their performance in other courses was least impacted by using the makerspace, followed by the ability to mentor or teach and the ability to act as a leader. It is notable that students do not feel their improvement in skills and abilities was very beneficial to other courses. It is clear that the students feel the makerspace has had positive effects on them, but judging by the scores there is still room for improvement.

The open-ended questions, "Which of your skills or abilities would you say were most improved by using the makerspace? What caused the improvement?" were used to gather additional information and were used to support the user skills/abilities evaluation. This question received 56 responses, with an average length of 14 words per response. To avoid biasing the responses, the open-ended questions were posed before the Likert scale question. Interestingly, the important themes found in the responses were very similar to the items listed in the Likert scale question. The most common trend found in the data related to improvements in technical skills. Students noted increased proficiency with simple hand tools as well as the more complicated 3D printers and wood-burner. This was noted in 66% of responses. Another common trend was improvement in design skill, being found in 20% of answers. The second theme clearly supports the high score given to item #2, but both themes help explain the score for item #10. The remaining themes found concerned improvements in leadership and management (5%), communication skills (4%), creative abilities (4%), and teamwork skills (4%). Despite showing up in the data explicitly, the rates of occurrence are too low to say these remaining themes do or

do not support the user skills/abilities evaluation. One student noted immense improvement in skill and ability from using the university makerspace:

> "Project Development, Organization, Time Management, Communication. I participated in an XProject over the summer which led, and is still leading, me to honing these skills even more so than I could have anticipated."

Information on non-users

As noted, the survey divided respondents into two groups – those who have used the makerspace and those who have not, representing 117 and 200 students, respectively. The purpose of this section of the survey was to determine who is not using the space and why.

Non-users consisted primarily of freshman and sophomores, representing 31% and 24% of respondents, respectively. The survey was released early into the Fall semester, so it makes sense that most freshman who answered the survey would not have used the makerspace yet. Bioengineering and Civil and Environmental Engineering each represent 18% of the respondents and are the two most prominent majors that do not make use of the facility. Most non-users were white (73%) or Asian (35%) with males comprising 53% of those surveyed while females comprised 47%. It is interesting to note that these demographics are different from those of the users, but with the response rate being low, it is difficult to say how representative this is of the majority of non-users.

Non-users provided useful information on why they had not used the makerspace. The primary reason they had not used the space was because nearly half of respondents were unaware that the facility even existed. Another 17% of students said they were too busy with other activities to spend time in the space. Around 8% of non-users said they simply had no interest in using the makerspace. Another selectable category was other where the respondent could enter a written answer. The largest and clearest theme found in the data was that a number of students who did know the space existed where unsure of how to go about getting access or if they even had permission to use the facility.

Conclusions

The primary purpose of this study was to perform an initial assessment of a makerspace at the University of Pittsburgh. This was accomplished by answering two key questions about the facility. These were if the makerspace was upholding its mission, and if and how the space was affecting its users.

From the results of the survey, it appears that the makerspace is achieving its mission and associated objectives. All items are at or above 3.50 on a 5-point Likert scale, all of which are critical to the success of the makerspace. The highest-ranked item was "The Makerspace encourages innovation in engineering" which is one of the main reasons the space was created. The themes found in the open-ended questions helped validate the item ratings by noting the sense of community among users and how the space promotes innovation, as well as the concerns about a lack of access to information about the facility, mandatory training, and to the

space itself. While these results are encouraging, it is important to remember that all responses are self-reported, and represent around 3% of the engineering student body. They do; however, represent 23% of registered users for the 2017 – 2018 year. Additional study is required to further validate if the makerspace is truly achieving its goals, and to what extent.

It is clear that the students feel the makerspace is having a positive impact on them. All items except one (3.48) are rated at or above 3.50 on a 5-point Likert scale, all of which are important skills and abilities in engineering. To prevent bias, the open-ended question addressing improvement in skills and abilities was asked before the Likert scale question. The themes found in the responses showed some support for the rated items by emphasizing improvements in technical ability and design ability, but they also validated the selection of the listed skills and abilities, as many of them, such as creativity, teamwork, and communication appeared in the open-ended responses. Again, the results presented here are self-reported, and only represent a small segment of the engineering student population. Further study is required to demonstrate significant improvements in students' skills or abilities.

It can be concluded that the makerspace is performing well; however, the survey showed that it could be functioning better by revealing certain issues. One issue is demographics. Like many other makerspaces, the users of the facility are mostly white and male, and women and minorities are underrepresented within the user group. Another issue is a misunderstanding of the purpose of the makerspace. The space is specifically focused on design iteration and rapid prototyping, but when users were asked what could be improved, many of the responses requested tooling that would be found in a machine shop. The survey identified other aspects of the space that could potentially be improved. Common themes observed in response to the question of what could be improved in the makerspace included mentor training, the atmosphere of the space (some students feel the space is divided into cliques), the perceived lack of information about the space, such as scheduled events, access to the facility, and the quality and availability of basic training. Finally, it is apparent communication could be improved between staff and mentors and non-users. Half of the non-users surveyed were unaware of the existence of the makerspace. Many other students that did know the space existed were unsure of how to use it or if they had permission to.

The evaluation performed, and conclusions drawn from the corresponding data add to the growing body of literature on makerspaces. In addition to examining the impact of the facility on students, the study also looked at whether the space is meeting its goals as part of a larger program at the university. The collected data also helped determine what practices could be improved. Although the study was done on a specific makerspace, the setup and operation of the facility are well-defined, and may potentially aid other colleges and universities in creating and maintaining their own makerspaces.

References

[1] U. S. National Academy of Engineering, "The Engineer of 2020: Visions of Engineering in the New Century," National Academies Press, Washington, D. C., 2004.

[2] M. Itani and I. Srour, "Engineering Students' Perceptions of Soft Skills," *Journal of Professional Issues in Engineering Education and Practice,* vol. 142, no. 1, p. 04015005, 2015.

[3] U. S. Department of Commerce, "The Innovative and Entrepreneurial University: Higher Education, Innovation & Entrepreneurship in Focus," 2013.

[4] V. Wilczynski, "Academic makerspaces and engineering design," in *ASEE Annual Conference & Exposition*, Seattle, WA, 2015.

[5] T. W. Barrett, M. C. Pizzico, B. Levy, R. L. Nagel, J. S. Linsey, K. G. Talley, C. R. Forest and W. C. Newstetter, "A review of university makerspaces," in *ASEE Annual Conference & Exposition,* Seattle, WA, 2015.

[6] C. R. Forest, R. A. Moore, A. S. Jariwala, B. B. Fasse, J. Linsey, W. Newstetter, P. Ngo and C. Quintero, "The Invention Studio: A University Maker Space and Culture," *Advances in Engineering Education,* vol. 4, no. 2, p. n2, 2014.

[7] D. W. Knight, L. E. Carlson and J. F. Sullivan, "Improving engineering student retention through hands-on, team based, first-year design projects," in *International Conference on Engineering Education*, Honolulu, HI, 2007.

[8] M. Z. Lagoudas, J. E. Froyd, J. L. Wilson, P. S. Hamilton, R. Boehm and P. N. Enjeti, "Assessing impact of maker space on student learning," in *ASEE Annual Conference & Exposition,* New Orleans, LA, 2016.

[9] M. Galaleldin, F. Bouchard, H. Anis and C. Lague, "The impact of makerspaces on engineering education," *Proceedings of the Canadian Engineering Education Association (CEEA),* 2016.

[10] R. J. Morocz, B. Levy, C. Forest, R. L. Nagel, W. C. Newstetter, K. G. Talley and J. S. Linsey, "Relating Student Participation in University Maker Spaces to their Engineering Design Self-Efficacy," in *ASEE Annual Conference & Exposition*, New Orleans, 2016.

[11] J. W. Creswell, Qualitative inquiry and research design: Choosing among five approaches (2nd ed.), Thousand Oaks, CA: Sage Publications, Inc., 2007.