Makerspace Participation: Which Students Visit, Return and Why?

Abstract

Makerspaces are becoming increasingly common facilities in engineering departments and universities across the country. Facility stakeholders, including students, professors, and university administration, hold many assumptions about the benefits and importance of the spaces, but little research has been done to quantify student usage and to evaluate participation within these spaces. This is especially important to understand given the interdisciplinary and multipurpose nature of these facilities. In this paper, we seek to understand which undergraduate engineering students use the Makerspace and what factors influence their likelihood to return. In partnership with a Makerspace at a large, public institution in the Southwest, we analyzed nearly 29,500 sign-in entries from 4,230 unique participants. Log-in information from these students included an open-ended response to their reason for visiting the facility, which was coded into five categories. We provide descriptives by major of the students, who visited the Makerspace within a two-year period, as well as results of chi-square analyses to determine differences in use of the Makerspace and results of logistic regression to determine the probability of students' return. Analysis of this data begins to uncover the ways in which undergraduate students engage with Makerspaces and illuminates differences in behavior between majors. Further research should investigate the reasons behind these patterns and possible barriers to entry.

Introduction

As rapid prototyping technology has advanced over the last few decades, the creation and expansion of Makerspaces on college campuses have paralleled this growth. In 2014, a systematic review found that 40 of the 127 highest ranked United States colleges and universities had documentation of a Makerspace facility publicly available on their school websites (Barrett et al. 2015). While the components and set-up of the spaces vary greatly between locations, a growing number of universities have shifted from more traditional machine shop equipment towards digital design and rapid manufacturing tools (Wilczynski, 2015). These technologies are available to students through their coursework, their participation in certain extracurricular activities, their status as an engineering student, or simply through their university enrollment.

Students visit the Makerspaces for academic, personal, and extracurricular projects (Ali et al. 2016; Wilczynski, Zinter & Wilen 2016). Since its establishment at the University of Texas at Austin in 2014, more than 30 courses offered by the university have included course projects that prompt students to utilize the Makerspace facilities in their academic work. Many researchers and faculty members are beginning to investigate the benefits of incorporating Makerspaces into course curricula and have argued that the development of tangible products allow students to recognize design flaws that would have otherwise gone unnoticed (Forest, 2014; Wilczynski et al., 2016).

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Furthermore, student organizations, such as Tau Beta Pi, the Society of Women Engineers, and the Society of Automotive Engineers, hold chapter meetings in the facility or encourage their members to use the space for club projects. Students often collaborate with their peers and engineering faculty on academic research, product development or personal projects. This wide range of potential uses of the space is seen in Makerspaces across the country and offers a strong impetus to examine students' motivations to visit the space. Furthermore, at UT Austin, a variety of engineering majors are offered to undergraduate students. After the introductory math and science courses, classes diverge by major with varying levels of built-in design and collaboration aspects. Therefore, it would be informative to further motivate the examination by major to see the extent to which major impacts Makerspace use.

This research study seeks to address three main questions.

1. How does students' first use of the Makerspace differ by major?

2. How does students' last use of the Makerspace differ by first use and major?

3. To what extent does the first semester the student visited the Makerspace, category of first use, and major predict the likelihood of returning to the Makerspace?

Methodology

In 2014, the UT Austin Makerspace opened its doors to engineering students and faculty. It hosts a wide array of equipment including 3D printers, laser cutters, CNC machines, and a variety of handheld tools. The space is available to all faculty, undergraduate and graduate students from the Cockrell School of Engineering. Faculty and student employees oversee the facility during its operating hours. Use of the studios is free to enrolled engineering students but may require preliminary training for certain equipment and/or associated material costs. Students are welcome to use the facility as a collaborative space, with or without using the equipment available there.

Data Source

As approved by the institution's IRB, the data examined in this study is the Makerspace's log-in data. Upon entering the space, students were asked to sign in on a google form. This form asked visitors to self-report: name, student ID number, major, educational status (undergraduate, graduate, faculty, etc), email, what they were using the Makerspace for, and which class they were using the Makerspace for. Name, student ID number, educational status, email, and "which class are you using the Makerspace for" were fill in the blank questions. Major and "what are you using the Makerspace for" were multiple choice, with the option to enter a response if they

selected the choice “other”. All responses were recorded with a time stamp and stored in a spreadsheet. This data, owned by the facility director, was later shared with the research team.

From the raw dataset, participants were retained if they met the following inclusion criteria: (1) listed a student ID number that could be matched to university records (2) were undergraduate engineering students; and (3) used the Makerspace at least once from fall 2015 through summer 2017.

Students at UT Austin are given a unique student ID, referred to as an EID, and were asked to enter this on the log-in form. This EID was used to track usage of the Makerspace within persons. If they did not provide an EID on at least one log entry, they were excluded from this dataset. While the Makerspace at this university is free for engineering student and faculty use only, the log data showed both non-engineering majors and visitors to the university signed into the space as well. For the purpose of this analysis, only undergraduate students enrolled in engineering were retained. The analysis was over a two-year time period, from the start of the fall semester in 2015 to the end of the summer semester in 2017. The Makerspace moved to a different building in the fall semester of 2017, so the time period was chosen to look at data from only the old location.

In cases of missing information, data was supplemented from other logs associated with the same student. For instance, while students were prompted to enter their ID, they often skipped the question or mistyped a response. Student name, major, and ID were identified by cross-referencing other identifying information from other sign-ins when those responses were left blank. In some cases where a student never typed an ID into the form, the university directory system was used to locate the information. Students who could not be associated with a university ID were removed from the dataset. A total of 4230 students remained in the final dataset.

The majority of the data processing for this analysis involved cleaning student responses. The drop-down menu for *major* in the google form was modified slightly during the time period of this study, resulting in multiple names for the same major. These were consolidated into eight distinct majors, matched to the degree programs offered by the university. *Status* was cleaned and grouped into undergraduate, graduate, and other, and all non-undergraduate sign-ins during this time period were removed from the data set. Undergraduate criteria included those who reported they were freshmen, sophomores, juniors, seniors, or undergraduates. When students were asked if they were visiting the space for a class, they typed entries in the form of course numbers, which are a mixture of letters and numbers. These entries were often mistyped. Identifying entries that corresponded to the same class code and consolidating on the various forms into the official university listed course number resolved this issue.

Focal Variables

Students' responses to "What are you using the Maker Studio for?" were categorized and coded into five categories: class, development, extracurricular, personal, and other. The log-in form had a drop-down menu with a few common options, such as class or hobby, and an 'other' option that prompted students to type their own reasons. For this analysis, *Class* was coded from entries that selected class, class project or entered a course number as the reason for visiting. In addition, a class was coded as required if it had at least one assignment that required use of the Makerspace. This list of classes was compiled from faculty interviews and the facility website. *Development* was coded from entries that selected research and development or typed in anything related to a specific research lab, prototyping, or training. *Extracurricular* was coded from entries that typed a particular organization, competition, or other outreach. *Personal* was coded from entries that selected fun, hobby, personal, or typed in something related to a personal project or repairing a personal item. *Other* was coded from entries related to using the Makerspace for collaboration, homework, browsing, and recreational activities.

For every student retained in the dataset, *first use* was created from their earliest log entry and the category of use they fit into at that log point. It should be noted that students may have entered the space prior to implementing this sign in system in the fall of 2015, so first use is the students' first recorded entry. Additionally, *last use* was created to capture the students' final visit to the Makerspace, regardless of their total number of visits. *Return* was a dichotomous variable coded "1" if the student visited the Makerspace more than 1 time. Semester was a categorical variable created to control for time. It was coded "1" for Fall 2015, "2" for Spring 2016, "3" for Summer 2016, "4" for Fall 2016, "5" for Spring 2017, and "6" for Summer 2017.

Research Design

To answer the first research question, descriptive statistics were calculated to characterize first use by major and category. Chi-squared analyses were used to compare Makerspace usage statistics to the Cockrell School of Engineering population and differences in the proportion of first use by major. To address the second research question, a chi-squared test was conducted to determine differences in last use by first use and major. Lastly, logistic regression was run to determine to what extent return (as coded 0=did not return and 1=did return) could be predicted by semester the Makerspace was visited, first use, and major. This final analysis addressed the third research question.

Results

First Use by Major

The majority of students who visited the Makerspace during this time were mechanical (37%), electrical/computer (25%), and aerospace majors (11%). Table 1 provides a breakdown of *first use* by major and the average representation of each major within the college of engineering from the same two-year period. When contrasted to the makeup of the engineering school, log-in data suggests an underrepresentation of chemical and civil students, and overrepresentation of mechanical students.

Across all majors, the majority of the students (52.5%) came for class. Approximately, 61.7% of the students visiting the space for the first time for a *class* did so for a class that required use of the Makerspace. Therefore, about one-third (32%) of first uses as a whole were for a class that required the Makerspace. The second most frequent category was personal use (32.7%), followed by development (9.7%). The remaining portion of the students came for extracurricular (4.2%), and less than 1% for some other reason. Table 1 shows a breakdown of first use by major. Chi-squared tests showed the differences in first use by major, X^2 (28, N = 4230) = 226.9, p =0.000.

Table 1: First use by major

Major	**Class**	**Development**	**Extra-curricular**	**Personal**	**Other**	***Total***	***% of COE****
Aerospace	159 (3.8%)	86 (2.0%)	54 (1.3%)	158 (3.7%)	6 (0.1%)	463 (10.9%)	10.5%
Architectural	67 (1.6%)	8 (0.2%)	2 (0.05%)	36 (0.9%)	3 (0.07%)	116 (2.7%)	3%
Biomedical	242 (5.7%)	38 (0.9%)	13 (0.3%)	100 (2.4%)	0 (0.0%)	393 (9.3%)	8.5%
Chemical	116 (2.7%)	23 (0.5%)	14 (0.3%)	146 (3.4%)	3 (0.07%)	302 (7.1%)	13%
Civil	137 (3.2%)	16 (0.4%)	9 (0.2%)	82 (1.9%)	2 (0.05%)	246 (5.8%)	10.5%
Electrical and Computer	535 (12.6%)	99 (2.3%)	46 (1.4%)	355 (8.4%)	11 (0.3%)	1046 (24.7%)	25%
Mechanical	912 (21.6%)	133 (3.1%)	36 (0.9%)	466 (11.0%)	12 (0.3%)	1559 (36.9%)	21.5%

Petroleum	51 (1.2%)	8 (0.2%)	3 (0.07%)	41 (1.0%)	2 (0.05%)	105 (2.5%)	7%
Total	2219 (52.5%)	411 (9.7%)	177 (4.2%)	1384 (32.7%)	39 (0.9%)	4230 (100%)	100%

*COE: College of Engineering. Average of the academic years 2015 and 2016

Last Use by Major

During the two-year period examined, approximately 72% of students returned to the Makerspace at least once. Of the students who revisited the Makerspace, 47.3% returned for class, 43.5% for personal, 5.8% for development, 3.2% for extra-curricular, and 0.2% for some other reason. A chi-square test revealed these proportions were statistically significantly different from those that only visited once, X^2 (4, N = 4230) = 27.8, p =0.000.

To address the second research question, we conducted additional analyses to determine if there were differences in the last use of the Makerspace by major and first use. Chi-square tests were statistically significant by major [X^2 (28, N = 3054) = 232.5, p =0.000] and first use [X^2 (16, N = 3054) = 757.1, p =0.000]. Table 2 shows the percentage of last use by major; the row totals for each major represent the percent of each major that had a return use. Each cell percentage was calculated by dividing the number of students who last use was in that category by the total number of students in the dataset in the respective major.

Table 2: Percentage of last use in each major

Major	**Class**	**Development**	**Extra-curricular**	**Personal**	**Other**	***Total % Return***
Aerospace	27.6%	6.3%	9.9%	28.5%	0.0%	72.4%
Architectural	42.2%	2.6%	0.0%	24.1%	0.0%	69.0%
Biomedical	45.0%	6.1%	2.3%	22.4%	0.3%	76.1%
Chemical	18.5%	2.6%	4.0%	34.8%	0.3%	60.3%
Civil	27.2%	2.4%	0.8%	23.2%	0.0%	53.7%
Electrical and Computer	36.4%	3.2%	1.2%	29.8%	0.4%	70.9%
Mechanical	36.8%	4.6%	1.0%	36.7%	0.0%	79.1%
Petroleum	13.3%	1.9%	1.0%	32.4%	0.0%	48.6%

Furthermore, to answer the third research question, we examined the probability of return by conducting a logistic regression. In total, we ran four models (Table 4). Model 1 included

semester; Model 2 added *first use* to Model 1; Model 3 added *major* to Model 1, and Model 4 included semester, first use, and major. The coefficients are presented in odds ratios where a value less than 1 means a lower likelihood of *return*.

At baseline, semester accounted for 3.4% of the variance in the return to the Makerspace. The addition of *first use* in Model 2 only explains an additional 0.6% of the variance in *return.* Model 2 shows that those going to the Makerspace for the first time because of *development* are statistically more likely to return, controlling for all the other variables in the model (p=0.017). Conversely, those going for the first time for *personal* are statistically less likely to return, controlling for all other variables in the model (p=0.000).

Model 3 shows the effects of major on *return* controlling for all other variables in the model. In comparison to mechanical engineering, all majors except biomedical engineering are less likely to return to the Makerspace (p<=0.001). Major accounts for 2.1% of the variance in *return* (Table 3, Model 3). Model 4 shows the inclusion of semester, first use, and major. In total, only 6.0% of the variance in students returning to the Makerspace was explained by what semester the students visited the Makerspace, major, and first use.

Table 3: Logistic regression predicting return to Makerspace

	Model 1	**Model 2**	**Model 3**	**Model 4**
		Odds Ratios		
Intercept	4.39***	4.87***	6.17***	6.57***
Semester (Fall 2015=reference)				
2	0.62***	0.60***	0.62***	0.60***
3	0.42***	0.39***	0.43***	0.40***
4	0.60***	0.58***	0.67***	0.65***
5	0.28***	0.27***	0.30***	0.29***
6	0.31***	0.30***	0.33***	0.32***
Use (Class=reference)				
Development		1.38*		1.43**
Extracurricular		1.18		1.30
Personal		0.72***		0.78**
Other		0.87		0.98
Major (Mechanical=reference)				
Aerospace			0.67***	0.64***
Architectural			0.47***	0.47***
Biomedical			0.83	0.81
Chemical			0.38***	0.40***
Civil			0.35***	0.35***
Electrical and Computer			0.62***	0.63***
Petroleum			0.34***	0.35***
Pseudo R^2	0.034	0.040	0.055	0.060

N=4230 *p≤0.05; **p≤0.01;***p≤0.001

Discussion

By examining first use patterns, we begin to understand the initial motivations for students using the Makerspace in relation to their major. *Class*, 52%, was the most common reason students cited for their first visit to the Makerspace. This means that approximately 1 in every 2 students came to the Makerspace for the first time to complete a class assignment. Nearly two-thirds of the students, who reported using the Makerspace for a class, used it for a class requirement.

Cumulatively, 32% of all students who visited the Makerspace for the first time did so out of a class requirement. This was approximately equal to the proportion of students who visited for personal reasons. Knowing that one-third of first-time visits were for a class requirement can motivate professors to design courses that require the use of the Makerspace, to get more students aware of and involved in the space.

We also saw distinct *first use* patterns by major. Seven out of eight majors reported *class* as the most frequent *first use*. Only chemical students reported visiting the Makerspace more frequently for some other reason, *personal*. Additionally, aerospace and petroleum students almost equally reported *class* and *personal* for *first use*. These patterns may be due to the variations in class projects across majors, as well as the types of classes that require students to visit the facility. Concerning the latter, there were seven mechanical; four biomedical; three electrical/computer; and one aerospace, architectural, chemical, and petroleum engineering undergraduate course that required the use of the Makerspace. This is certainly an area of future examination.

Overall, during the two-year period examined, approximately 72% of students returned to the Makerspace. In order of overall rate of return by major, mechanical returned most often followed by biomedical, aerospace, electrical/computer, architectural, chemical, civil, and petroleum engineering. Mechanical students returned at a rate of nearly 80%, while petroleum engineering students' return rate was less than 50%. Four majors cited *class* as their reason for their *last use* (architectural, biomedical, civil, electrical/computer), three majors cited *personal* (aerospace, chemical, petroleum), and mechanical was almost equal between *class* and *personal*. This completely differs from *first use* where only chemical students cited *personal* as their most cited reason. The increase in the proportion of students using the Makerspace for personal use is the most notable change from *first use* to *last use*. This indicates that students may be coming back for personal use after they have been introduced to the space through a class – notably, *class* and *personal* make up over 90% of the total *last use*.

Additionally, those going for the first time for *personal* are statistically less likely to return. Efforts should be made to encourage and support participation on a personal level with more guided instruction and employee help. Additionally, more examination can be done on what sorts of activities are involved in *development* as students naming this reason for the first time are statistically more likely to return. Lastly, knowing that all majors except biomedical are less

likely to return to the Makerspace compared to mechanical, efforts should be made on a departmental basis to encourage Makerspace participation. With the noticeable differences in Makerspace use and return among majors, department specific initiatives could be very influential.

Limitations

The dataset examined had limitations. Students were asked to sign-in upon entering the facility, but it may have been possible for some to bypass the login system. However, the sign-in computer is located at the only entrance of this Makerspace and signing in is strongly encouraged by the employees of the space. Sign-in reminders were also posted throughout the space, so lack of use without documentation was minimized. A class was considered required for this analysis if it had at least one assignment that required use of the Makerspace. From the data, there was no way to distinguish if students coming for a required class were working on that particular assignment that required the Makerspace. Additionally, the selected time period for analysis, may impact the researcher's understanding of *first use* versus *return use* behaviors since a student may have entered the space before the selected time period. Another limitation is that students were asked to self-report key items, including their reason for visiting, which introduces unavoidable error into the analysis.

Conclusion

This study sought to understand patterns of student use behavior across engineering undergraduate majors as they visited the Makerspace at UT Austin. While the nature of this study was primarily exploratory, it did point to some actionable findings and areas of future research. Overwhelmingly, students visit the Makerspace to fulfill a class assignment, especially for their first use. Understanding that students are being drawn to the Makerspace for this reason, warrants more research on where these spaces are located, how they are designed, and for what students are being sent to these spaces to do. Professors can promote these spaces in their classes to raise the level of awareness. This is particularly important for Makerspaces that are located in less prominent spaces such as basements of engineering buildings. Professors can also more strategically partner with local Makerspaces to develop assignments that complement the learning objectives of their courses and welcome students to return.

In connection to other educational outcomes, future research in this area could explore a more detailed analysis demographically (i.e., race, gender, age) as well as what type of students are using specific equipment and how that influences their attitudes and beliefs related to engineering such as self-efficacy and engineering identity. This also points to the importance of partnerships with institutional makerspaces and educational researchers to develop strong research designs. Purposeful sampling of specific groups of students could be one way to gather meaningful data on student behavior. The quality of the data available to researchers is critical to

the conclusions and recommendations that can be made about makerspaces. Both quantitative and qualitative studies would benefit from this intentional partnership. As best practices are discovered, these spaces can be designed or redesigned to promote student engagement that can further advance positive educational outcomes, creativity, and innovation that reaches within and beyond the engineering field. By analyzing how and which students use the Makerspace, we can better understand if, and how, Makerspaces function as productive learning environments for engineering undergraduate students.

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