

Toward Understanding the Design Self-Efficacy Impact of Makerspaces and Access Limitations

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Introduction

There is an ongoing effort to foster creativity and innovation in engineering students. With a limited amount of time available for students to learn these skills in a classroom setting, it is important to create environments outside of the classroom where students can refine their engineering and creative skills. University makerspaces might offer the perfect setting for students to participate in collaborative and multidisciplinary projects that will allow them to succeed as professional engineers. To that end, many universities have created or are in the process of creating new makerspaces. Many makerspaces blend new manufacturing technologies like 3-d printing and laser cuttings with more traditional woodworking and machine shop tools. Little data exist, however, about what the impact of university makerspaces is on the students who choose to participate in those spaces. In order to better understand this impact of university makerspaces, our research team is conducting a multi-university longitudinal study.

To measure the impact of making environments, this study looks at different metrics such as GPA, design self-efficacy, retention, and idea generation ability and how these metrics are affected by different levels of involvement in university makerspaces. Preliminary results (two of four years are completed) from the longitudinal studies raised additional questions related to developing an inclusive and accessible space with an informal learning culture dedicated to making. Toward answering these questions, preliminary studies have been run (1) using people counters in making spaces to understand the flow of students through a space and (2) using ethnographic techniques to explore the culture present in university makerspaces. A review of progress made across all parts of the study will be presented in this paper.

Background

Why make? Ask (2016) defines three motivations for making: Invention – or the quest to solve a problem, Art – the desire to create beauty, and Process – the love of the activity of making. A maker who stands before you will harness one if not all of these motivations in order to create. Motivation is critical to accomplishing a task. For students, in particular, there is the constant demands of inspiring and motivating them to solve problems, learn, and make an impact. When making was introduced into school-based K-12 programs, the coordinators focused on initiatives to have students build using technology in order to increase the students' self-esteem (Blikstein, 2013). The program was grounded in theories of progressive education (Dewey, 1998), constructionism (Papert, 1980), and critical pedagogy (Freire, 1970). Crafting an environment that supported such initiatives led to the development and rise of educational makerspaces. These makerspaces allow students to engage in the iterative design process – failing and repeatedly redesigning until a final product results. Such a process facilitates learning as students seek out and implement physics and engineering equations while also

seeing the immediate impact of theory in practice in a low-stakes project. Even the smallest of successes can empower users in the space, regardless of former engineering knowledge. Kurti, Kurti, and Fleming (2014) propose that embracing failure, expecting things to break, and collaborating with others are three essential principles that guide the educational makerspaces. Motivation to embrace failure, breakage, and collaboration can be a challenge to students, yet very rewarding.

These benefits of making and makerspaces, however, can only be available if the space fosters an open and accessible community for the very individuals to whom it was designed to serve. As demonstrated through recent ethnographic attempts to study these spaces, access into a makerspace emerges in a variety of forms, including how easy a space is to enter, how one is introduced and oriented to the space, and how the space is physically designed (Penney et al., 2016). Such accessibility to a makerspace, in general, can impact how students perceive making and even how they perceive themselves as a maker (O'Connell, 2015). A space becomes successful and sustainable through providing access to technology and partnerships (Myers, 2015).

Beyond access, other literature noted best practices include: proper training for users, a clearly defined mission, encouragement of collaboration, accommodation of student work schedules with operational hours, and supportive, available staff (Wilczynski, 2015). In Barrett et al. (2015), makerspaces from across the United States were evaluated to identify common features and trends including staffing methods, equipping practices, and capabilities. In general, though, if a makerspace is to be successful, it should be supported by a rich making culture and community on the college campus (Wilczynski, 2015). The fundamental research question that follows then is:

What fosters the culture that is necessary to develop a vibrant making community?

Methodology

This research project began by asking *what is the impact on engineering students as a result of using engineering makerspaces?* We believed that perhaps the answers to this question lie in a change in design self-efficacy based on activities noted in makerspaces. Correlations in makerspace usage and design self-efficacy are indeed prevalent in student makers, but it seems that there are more existing and unknown correlations. To get at these impacts, the research team turned to ethnographic approaches, but as our understanding of engineering makerspaces grew, we learned that there is an underlying theme of *access* related to makerspaces that required understanding before broader questions related to student learning and self-efficacy could be addressed. In the following three subsections, the methodologies related to studying design self-efficacy and ideation ability as well as access (ethnography and people counters) are described.

Study One: Longitudinal Quantitative. Data on GPA, design self-efficacy, retention, idea generation ability, and makerspace involvement are collected on mechanical engineering

students at three different times throughout their undergraduate career at a large, public, R1 university in the southern United States (Site One, Data Set One). Data on GPA, design self-efficacy, and makerspace involvement are collected on undergraduate engineering students at a large, comprehensive, public university on the East coast in the United States (Site Two, Data Set Two) and at a predominately Hispanic-serving southern public university (Site Three, Data Set Three). With respect to the Longitudinal Quantitative study, this paper reports on longitudinal data collected as a part of data set one.

Data in Data Set One started being collected in the Fall 2015 with the freshmen, sophomore, and senior students in a freshmen entry level required course, a sophomore design course, and capstone courses, respectively, in the mechanical engineering discipline. Assessments were taken in the Spring 2015, Fall 2015, and Spring 2016. For the Fall 2016, only sophomore and freshmen students were assessed. These assessments are presented during class time where the students are given a survey that combines information on demographics, self-efficacy, and makerspace involvement. Other than that, the authors accessed the student GPAs and offer incentive to participate in an idea generation study. The current paper presents a summary of the work completed thus far (Morocz, Levy, Forest, et al., 2016).

Descriptions of the instruments used follows:

- *The Self-Efficacy Survey:* The students were presented with the engineering design self-efficacy survey that was created by Carberry et al. This survey was implemented in order to understand the students' self-assessed measure of their confidence to completed engineering design tasks. The survey includes four self-concepts: self-efficacy or self-confidence, motivation, expectancy of success, and anxiety (Carberry, Lee, & Ohland, 2010). These self-concepts are identified with different engineering design tasks (i.e. identify a design need, research a design need, develop design solutions). The first engineering design task, conduct engineering design, is considered to be an overarching task, where the student's response to this question refers to their overall confidence in their ability to do engineering design. This first task is used to calculate the engineering design (ED) score. From there, the student responses for the following eight engineering design tasks are combined and considered to be relatable to the ED score. This score is known as the engineering design process (EDP) score. The first score (ED) refers to the self-assessed ability to conduct engineering design whereas the second score (EDP) refers to the self-assessed ability to do different engineering design tasks that are sufficiently what engineering design is comprised of.

Student Involvement Survey: For purposes of this research, a survey instrument was created in order to investigate student engagement and usage of makerspaces. The instrument was initially built based on experience of the researcher. Throughout several iterations and with the assistance of experts in survey design and theory, the survey instrument was finalized and implemented. To differentiate between users and non-users, the survey consisted of three sections dedicated to student exposure, involvement, and participation in a makerspace. Exposure investigated the question,

“Has the student used the makerspace?” which made for the ability to identify non-users. Involvement sought to answer the questions, “How often does the student use the space? How much time do you spend in the space?” where more time in the space corresponds to higher involvement. Participation explored the question, “Why is the student going into the space?” which helped to provide an understanding of the motivating factors of makerspace users.

- **Idea Generation Study:** Through solving open-ended design problems and creating new devices by way of internal motivation, students are believed to become more innovative and creative designers. The devices and projects that students choose to create and work on, respectively, showcase innovation and novelty. Fostering an innovative atmosphere, makerspaces also expose students to a wide variety of rapid prototyping techniques, manufacturing skills, and design solution approaches. In consequence, this likely builds their knowledge of manufacturing and design which in turn fosters their overall engineering capabilities. As such, it is fitting to question whether participation in makerspaces impacts students’ ability to generate relevant engineering ideas to a design task or problem. Students’ idea generation ability is being measured utilizing high validity design problems, such as the Peanut Sheller problem, that have been used in multiple previous studies and have been shown to be effective for assessing engineering student design and creativity abilities (Fu, Cagan, & Kotovsky, 2010; Linsey et al., 2011; Linsey, Green, Murphy, Wood, & Markman, 2005; Linsey et al., 2010; Tsenn, Atilola, McAdams, & Linsey, 2014). Students’ idea generation ability is being measured during their freshman, sophomore, and senior years. Students who are highly engaged in makerspaces will be compared with students who are less engaged. Data is still being collected.

Study Two: Ethnography. Ethnographic techniques were employed to more fully understand the context surrounding the results from the data collected during the Longitudinal Quantitative study. Ethnographic methods of participant observation as well as unstructured and semi-structured interviews have been performed at both Site One and Site Two to gain insight into the features of makerspace culture. Qualitative data were collected by multiple observers for 18 months, resulting in 243 pages of single-spaced field notes, ethnographic interviews, and maps, and a total of 51 photographs. In total, four undergraduate researchers and one graduate researcher have conducted observations and performed semi-structured interviews as a part of this research with 1 month of data being collected at Site One and 17 months of data being collected at Site Two.

Site One hosts numerous makerspaces across the campus. Their first and main makerspace supports all disciplines on the campus, despite being housed in a mechanical engineering building. This makerspace provides access to 3-d printers, laser cutters, waterjets, a metal working shop, and a woodshop. While the space occupies 4,000 square feet, students are free to work on projects that suite their current endeavors, from personal to class-related or research to entrepreneurial endeavors. Trained student volunteers supervise the day-to-day activities in the space to maintain safety, efficiency, and productivity.

At Site Two, there has been a push across campus to engage students in more innovative, entrepreneurial, creative, and collaborative endeavors. Out of this push came spaces equipped with virtual reality displays, 3-d printers, laser cutters, photographic printers, and wood-cutting machinery. Of these spaces, one centralized space occupies a location in a separate building which is open for all disciplines to use whether for personal, research, or class-related projects and also supports classes geared towards teaching students how to use the equipment. More recently, space has been renovated into makerspaces in the engineering building at this institution. The rooms for making are centralized to one floor where there is a prototyping room with 3-d printers, laser cutters, and workbenches; a fabrication room filled with drills, lathes, and other woodworking machinery; and a machining center for metalworking and higher-end machinery. The space is currently under renovation with design facilities and spaces for collaboration to come. These spaces support the engineering curriculum and inspire a culture for making and creativity. These spaces are staffed by a lab manager, trained students, and technicians.

Student researchers engaged in methods of participant observation, engaging the makerspaces as both observers and learner-participants. Researchers' observations included not only participation in the makerspaces across both campuses, but participation in student working groups discussing and utilizing those makerspaces. Thus, data collected included both behavioral activities in the makerspaces and student perceptions of those makerspaces. Ethnographic interviews with students in the makerspaces served as member checks to refine emerging interpretations of the data. Data were analyzed by the research team's social scientist using methods of constant comparison; data were comparatively examined line-by-line to systematically identify emerging themes (Charmaz, 2000). Primary and secondary cycle coding were employed (Tracy, 2013) and reported in this study resulting in a typology of issues related to the accessibility of makerspaces on campus.

Preliminary results from Site One and the first 12 months of data collection at Site Two are reported in (Penney et al., 2016). Initial results provided clues on the context surrounding the quantitative longitudinal results, but also raised issues around access and inclusivity as discussed in the Results section.

Study Three: People Counter. Initial efforts to understand access and inclusivity focused on understanding the flow of individual users into and out of the space. This effort was chosen due to some studies suggesting that the amount of people who use a university makerspace can be a measure for the success of a makerspace (Forest et al., 2014; O'Connell, 2015; Weinmann, 2014). In practice, though, measuring the amount of people who move in and out of high traffic spaces such as a makerspace presents difficulty. Having students sign-in for when they are using the space has been one solution; however, this can create a barrier of entry and become a nuisance to the students. In efforts to record the amount of people entering a makerspace on a given day in a non-obtrusive manner, we installed an automatic people counter (APC) system at Site One. While typically APC system are used for industries for managements and security reasons, the APC system would be able to provide accurate data

without needing a researcher sit in the room and count the people passing in and out in a given day. The system was situated in the 3-d printing room, the room most common for student use and with the highest traffic. In juxtaposition with the APC, a camera was situated towards the door in order to distinguish between the number of individuals who use the space each day and the number counted by the APC system. In other words, a student may enter into the space multiple times a day in order to start a print, check on a print, and collect a print. The APC cannot distinguish between individuals and we were interested in capturing the number of students who use the space. Therefore, we collected data during open hours from 5 days out of January and February. We used the camera footage to count the amount of individual who actually used the space and compared this with the count data. The data was then analyzed using linear regression. Results from the people counter study can be found in Morocz, Levy, Nagel, and Linsey (2016) as well as Morocz (2016).

3-d Preliminary Results

Study One: Longitudinal Qualitative. The data of the self-efficacy survey and involvement survey were juxtaposed in order to evaluate how high and low participation corresponded to motivation, confidence, expectancy of success, and anxiety. For motivation, confidence, expectancy, and anxiety, the ED and EDP scores were analyzed via Pearson Correlation as a means to validate the instrument. The resulting correlation was high, demonstrating that it was valid use the instrument.

Comparing the data of Fall 2015 and Spring 2015 freshmen students, there was only significant difference between confidence. Students in the Fall had more confidence than students in the Spring semester. As such, the data for the Fall and Spring 2015 was combined for analysis regarding self-efficacy and separated by high and low participation. Both ED and EDP scores demonstrated that between high and low participation groups, significant difference occurred for motivation and anxiety. Students with higher participation had higher motivation and students with higher participation had less anxiety. This suggests that students who have high participation in the makerspace are more motivated and less anxious in engineering design. While these are favorable results, this can indicate that makerspaces are helpful for motivating students and decreasing anxiety. However, the correlation indicates two alternatives: 1) more motivated and less anxious students are the ones who seek out makerspace activities or 2) the makerspace builds more motivated and less anxious students. Nevertheless, the makerspace is an avenue that does have some impact on motivation and anxiety, where anxiety becomes a barrier to entry. Initiatives, such as slowly introducing students to the space, can lessen students' anxiety about the space and help them to feel more comfortable approaching space. Unfortunately, such findings require qualitative research approaches in order to more fully understand how anxiety impacts the space and what the barriers to entry are.

Further investigation sought to compare low participation students between semesters and the high participation students between semesters. For high participation students, there was no statistical significance between any of the concepts, both ED and EDP. This is presumed to be the case because students who have high participation are always confident. For low

participation students, confidence and motivation were calculated as statistically significant between Fall and Spring for both ED and EDP scores. The students in the Fall were more confident and more motivated than in the Spring. Anxiety and expectancy for success were roughly the same. More in-depth analysis revealed that there might be a group of low participation students in the Fall semester with high motivation and high confidence who sought out the makerspace and became high participation students in the Spring semester. Typically students are not aware of the resources available to them and the makerspace on campus. Therefore, after the students have time to adjust to college life and explore opportunities, they find the makerspace and become involved which then transfers them into the high participation group for the Spring semester. Once again, this demonstrates that means to introduce students to makerspaces could produce more involvement in the space.

The idea generation survey is currently undergoing data analysis. Findings have yet to be reported.

3-d3-dStudy Two: Ethnography. Qualitative data analyses revealed five themes related to accessibility of makerspaces: Physical Characteristics, Material Resources; Interactive and Social Features, Emotional Qualities, and Student Content and Process Knowledge.

Physical Characteristics of makerspaces served to either constrain or enable students' experience of those spaces as accessible. Physical characteristics include the geographical location on campus or in a building, gateways to those spaces, structural design and features of the spaces, and interior design features. Physical features of the environment that served to enable students' perceptions of access ranged from effective signage above equipment and machinery, to furniture that made the room both functional and comfortable. In addition to structural features of the environment, aural characteristics such as music served to make spaces more inviting and "laid back," as well as offered a buffer to the loud backdrop of the machines.

More often, the data revealed the ways in which features of the space served as a barrier to access, including locked doors, cluttered and crowded rooms, and poor directional signage. Organization of the makerspaces in relation to one another prompted reflections on the impact of having equipment spread throughout multiple rooms and the inconvenience of "having to travel from room to room to get things done." The placement of equipment in a given room impacted students' access to it and to problem-solving, for example:

The print material is kept behind the computer and is brought down behind the printers and then into the printer. While he was trying to feed the material down the back of the machines I noticed he was having trouble. It seemed as though it would be helpful if he could have gone behind the machines to feed the material but the printers are pushed up against the wall and there is not room to do so.

In addition to barriers to access equipment and supplies, clutter in the room limited students' ability to work and create in the space. Interestingly, researchers reflected that an "empty" and

pristine room was uninspiring to innovation (a psychological barrier), but that too much clutter limited the opportunities to use the space: “It looked like a bomb had gone off in the small fabrication area in this space. There were materials absolutely everywhere, covering every surface. It looked to me like the space was in dire need of a sweeping.”

Material Resources available in makerspaces served to impact students’ perception of the productivity and value of the spaces and latently served to impact how accessible the spaces were toward meeting their needs. Students’ excitement around the materials available to them was an important aspect of access to learning opportunities. In one case a staff member was “excited to tell [the researcher] all about the different materials they used and showed [her] a bunch of different samples.” Students routinely commented on the value of outlets and monitor cords that allowed them the mobility to work in the diverse spaces. Broken equipment and not enough machines were viewed as a constraint to the accessibility of the spaces, leading to waiting and lengthy turn-taking lines. Finally, material resources were tied to the physical features of the spaces, as equipment might be off-line due to issues such as ventilation needs.

Interactive and Social Features of the makerspaces refer to the relationships and forms of communication that are supported or limited. The most complex finding, this theme reflects issues regarding how the culture and community itself is cultivated in campus makerspaces. Student perceptions of access are tied to issues such as rules and authority over spaces, relationships with other students and faculty in the spaces, and temporal factors such as time spent in the room. Initial findings suggest that the interactive and social features of makerspaces are related with the others themes in complex ways and are critical to understanding how communities of practice are developed around making.

“Helping” interactions are an important part of the interactive accessibility of the makerspaces. As one researcher observed, “It is a community feeling that everybody wants to help everybody.” Ease of access to faculty and informal student-faculty interactions facilitate this helping environment. Indeed, if “helping” is a rule in makerspaces, students and staff who violated those expectations closed off learning opportunities. Consider the following example,

Once the presentation was over I went back up to the girl who had helped me, she was talking to friends. I asked if either of them worked here and could help. The friends said I’m not on duty and I have flip-flops on. The other one responded with ‘I’m not on duty either.’ I immediately felt out of place and a bother.

In this interaction, the student worker ultimately helped the researcher, but did so reluctantly. While the helping relationships between students and staff are important to access to learning, peer relationships and the comfort therein appear far more important to the culture that is created in the makerspaces. Students described feeling most at home in those spaces that they used a lot, where they could count on interacting with friends and classmates. For example, one student reported that it is “not so much the room design itself that creates the comfort, but more so the people that are in the room.”

The *Emotional Experiences* of the students while in the makerspaces are noteworthy and important to consider. Not surprisingly, we cannot extricate the emotional experiences from the other themes. For example, spaces may be experienced as “open and inviting” because of design features, just as others may feel “overwhelming” because of the size and amount of machinery in the room. Emotional themes related to design deal with students’ perceptions of the affect that is created in the makerspaces, such as wall colors and ceiling heights as inviting or distracting, entryways as intimidating or welcoming, among others. Peer interactions can play an important role in socializing students to how they are to experience a makerspace. In a tour given to one of the researchers, the tour guide described the machine shop as one of the “scariest” rooms, telling her “even when you are trained you need someone else there to watch over your shoulder because every machine in there could kill you.” The use of words that students and staff use to describe the rooms and the equipment therein could have a powerful impact on the student. Interestingly, this description of the machine shop was offered to the female researcher, but not to the male researcher. Exploring how descriptions of space are gendered and implicate the affect felt in those spaces is an important area of future inquiry into potential barriers to access.

Finally, *Student Content and Process Knowledge* addresses broad issues related to students’ knowledge regarding how to gain entry access, when such spaces are available for use, and how to use equipment once in those spaces. This final theme relates closely to emotional barriers to space, as students report feelings of intimidation related to their lack of knowledge, for example. Further, the “helping” behaviors, or lack thereof, contributes to the knowledge that can be acquired in the spaces. While some spaces are highly governed by required training and rules, others are observed as “do it yourself” spaces, where students must be self-taught to use the equipment. Knowledge is enabled in the spaces through complex social interactions in which peers or staff walk students through the steps of making, as well as through simple posters that offer step-by-step instructions. In some cases, knowledge is acquired by overheard conversations and peers’ questions. For example, “Another person in the room chimed in and asked about the resolution of each of the printers. I listened in to the conversation and learned that the smallest one to the left back when you walk in has the best resolutions.” In multiple instances, students reported that while training in some of the spaces is required, they likewise opined “if you are confident enough then you can use them.” That is, knowledge is something that is demonstrated through confidence in the use of the equipment. That confidence, whether rooted in knowledge, yields access.

Further, knowledge is constrained when those helping students use jargon and vocabularies that are inaccessible to the learner. For example, in attempts to offer students specialized vocabulary, the result may be blocking access to knowledge acquisition and full use of the equipment itself: “[I] asked if all the printers did the same thing, which he replied ‘no,’ and began explaining all of them in terms I did not understand and therefore do not remember.”

Importantly, the themes in this typology that constrain and enable students’ perceptions of the accessibility of the makerspaces are interconnected and inform one another. For example, the physical features of the space, such as interior design, impact the level of interactivity in that

space, as one student notes: “There is nothing exciting. The front door is like an airport lounge where people are just sitting there by themselves, listening on their headphones, and not talking. It’s not a space that is conducive for working.” The nature of the interactions in the makerspaces will impact the kind of knowledge that is created or constrained, as one researcher observed “many people need help, [but there are] not always enough staff in makerspaces to help.” Further data analyses will need to reveal the ways in which each of the features in the typology are related and impact the others.

Study Three: People Counter. This study sought to validate the methodology for data collection, the precision of the APC technology, and the correlation between the APC counts to the individual users in the space.

Validating the Methodology involved two researchers independently viewing and analyzing one full day of camera footage. This not only accounted for validating the data, but also was to ensure accuracy and elucidate confirmation bias. The researchers identified users and the reappearances of these users by watching the camera footage at 30 minute increments. In the end, the researchers came to the same total of users in the space and differed in individual user count by 1.21%. This demonstrates that the data collection methodology is valid.

Validating the APC Technology consisted of comparing the manually collected data to the count data from the APC unit. In order to measure APC accuracy, the confidence interval (C.I.) between the manually collected data and the automatic count data must be calculated at a 95% confidence level. When the calculation results in the value zero residing in the C.I., there is subsequently no difference between the manually collected data and the automatic count data, indicating that the APC technology is accurate. For the five sample days that were being evaluated, the calculation resulted in the value zero falling within the C.I., thereby demonstrating accuracy. For further validation, the average precision for the APC technology was calculated (standard error of sample/average APC_{IN}) to be at $\pm 5.34\%$, and presumably, more sample days evaluated would lower the precision value.

Correlating the APC Count data to the number of individual users in the space was found by watching the camera footage and counting the number of individual users who used the space for each of the five sample days. A user was someone who came into the room at a distance of at least three steps. For example, a person could walk into the room three times a day. Whereas the APC technology would consider this to be three counts, the reality was that this was one user and therefore should be considered only once. It is this correlation between what the APC technology was counting and the actual number of persons who use the space that are of interest. The correlation was calculated as a user ratio where the individual user count was divided by the APC count. For the 3-d printing room, the ratio indicated that the average user enters the room approximately twice a day, which is appropriate for the 3-d printing room where users print an object, leave the room, and return to pick up the print later in the day. When more data samples are collected and analyzed, we will be able to expand this correlation into a linear regression. The user count data was also used to examine demographics and gender in the space via the camera footage. Certain characteristics were identified for female

users (i.e. hair style, clothing, body type, etc.). The results showed large variability between sample days of female users and that the percentage of female users was lower than the total enrolled at the university.

This correlation was used to identify the actual user patterns throughout the semester. The APC counts were adjusted according to the ratio of user count to APC count. This correlation revealed that patterns of high user traffic and was able to be used to determine the average user traffic in day-to-day.

Discussion

In our efforts to understand what fosters the culture that is necessary to develop a vibrant making community, we have taken various approaches in order to begin to investigate the impact that engineering makerspaces have on engineering students. It was clear in our initial efforts of survey development and implantation that there was a greater depth and more openness to the questions that we were asking about makerspaces. These three studies that we have presented here address our current state of research on makerspaces. While it constitutes both a review of previous literature that has been published and new findings, this papers aims to showcase how to integrate different approaches for studying a highly complex and uncontrolled space. Longitudinal data of design self-efficacy, retention, GPA, demographics and makerspace involvement are all being collected. In order to interpret and expand on the data, we pursued implementing an ethnographic approach in order to capture a more accurate and detailed account of what actual usage of makerspaces are. To supplement this, we recognized that ethnographic work requires the effort, time, and attention of a human researcher. Humans are limited in their time, attention, and effort, where ethnographic work is very time-consuming and fatigue-inducing. Actively paying attention to the details of the events can be a heavy cognitive load. In order to still capture usage while remaining non-obtrusive, we reconciled to having an APC unit installed into the makerspace room with the most traffic. In this way, we would still be able to capture usage through the lens of a video camera and people counter. In particular, we were able to identify when there were increases and decreases in the traffic at the makerspace, assuming that this same traffic patterns were transferrable to other rooms of the makerspace. This higher traffic dates indicated why students were using the makerspace more, falling around holidays and deadlines for class projects.

Conclusion and Future Work

The preliminary data from the longitudinal study and other sources indicated that much richer information was needed. From the ethnographic research, we found that there were critical issues of access that would not have been discovered using the longitudinal study's data collection methods. Furthermore, it is clear from the people counter study that there is significant fluctuation due to class, personal projects (Valentine's Day), and extracurricular. The usage data clearly indicates that personal projects also drive students to enter the space. This would not necessarily be made known through the ethnographic or longitudinal studies.

Understanding the complexity of a makerspace warrants a mixed-methods approach in order to capture the vibrancy of the space and the impact that it has on engineering students.

Future work aims to expand on the current findings of this work. The longitudinal study will continue to follow the freshmen class of 2015 until graduation. Ethnographic approaches will pursue understanding the barriers to access along with how students overcome and perceive these barriers. The people counter study will further investigate when students use the space the most.

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