Investigating Why Students Choose to Become Involved in a University Makerspace through a Mixed-methods Study

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Abstract

Makerspaces have observed and speculated benefits for the students who frequent them. For example, previous studies have found that students who are involved in their campus's makerspace tend to be more confident and less anxious when conducting engineering design tasks while gaining hands-on experience with machinery not obtained in their coursework. Recognizing the potential benefits of academic makerspaces, we aimed to capture what influences students to become involved in these spaces through a mixed-method study. A quantitative longitudinal study of students in a mechanical engineering program collected data on design self-efficacy, makerspace involvement, and user demographics through surveys conducted on freshmen, sophomores, and seniors. In this paper, the student responses from three semesters of freshmen level design classes are evaluated for involvement and self-efficacy based on whether or not a 3D modeling project requires the use of makerspace equipment. The study finds that students required to use the makerspace for the project were significantly more likely to become involved in the makerspace.

These results inspired us to integrate a qualitative approach to examine how student involvement and exposure to the space are related. Using an in-depth phenomenologically based interviewing method, purposive sampling, and snowball sampling, six females, who have all made the conscious decision to engage in a university makerspace(s), participated in a three-series interview process. The interviews were transcribed and analyzed via emerging questions for categorical metrics and infographics of the student exposure and involvement in making and makerspaces. These findings are used to demonstrate 1) how students who do, or do not, seek out making activities may end up in the makerspace and 2) how student narratives resulting in high-makerspace involvement are impacted by prior experiences, classes, and friendships.

Introduction

On several college campuses, makerspaces have become a hub of creativity and innovation. With equipment to rapidly build prototypes, space for collaboration between students, and an open and inviting atmosphere, these spaces are an ideal place for informal learning and developing skillsets in engineering design. While each university uses a different model to manage upkeep and safety in their makerspace, several schools have taken up an open access model, allowing any student to use the space with little or no previous training [1, 2]. This open environment may facilitate a sense of belonging for students, which has been shown to improve retention, particularly for underrepresented groups [3]. Additionally, those working in these spaces gain skills crucial for developing engineers. Makerspace users have reported an improvement in their ability to communicate engineering principles, especially to non-engineers [4]. Makerspaces also allow students an opportunity to become acquainted with the design process through trial and error while developing design skills through fabrication [5]. To engage students in these spaces, some curricula require the use of the space for certain design courses (such as the program studied herein), while other schools have kept space use as an optional perk for students. This leads to several questions about what kind of students are choosing to partake in makerspaces use, what factors drive students to initially and continually participate in makerspaces, and what is the impact that involvement has on the development of design skills.

Participation in academic makerspaces has been studied in a variety of contexts. For example, Wilczynski [2] observed makerspaces in order to understand the factors leading to successful spaces and found that makerspaces require clear mission, proper staffing, openness, available training, maker mindset, and accessibility. Other studies have identified the staff-user ratio and the floor space-user ratio as factors for success [6] as well as sustainable faculty leadership, management, and mentorship as critical elements for nurturing student values and co-ownership [7].

There remains, however, a need to understand how participation in makerspaces impacts student development as engineers. Are these open, hands-on making environments actually helping students to learn and to build confidence and motivation toward engineering design? Toward answering this question, the juxtaposition of qualitative and quantitative research methods used herein allows us to investigate the impact that these spaces are having on student motivation and confidence in engineering design [8]. This paper presents results from mixed-methods research consisting of a longitudinal quantitative study and a qualitative interview study focused on understanding the factors leading toward student involvement in makerspaces.

Background

The longitudinal study presented in this paper consists of a survey that gathers information from students on their involvement in the makerspace, self-efficacy for conducting engineering design tasks, and demographic information. This study collects data from mechanical engineering students at three points during their curriculum: a freshman-level engineering design course, a sophomore-level design course, and capstone design. The goal of the study is to observe the impact of makerspace involvement on students' self-efficacy toward engineering design.

Previous studies have identified correlations between makerspace involvement and engineering design self-efficacy [9]. Hilton, et al. [10] found that voluntary involvement (i.e., choosing to participate for non-curricular reasons) in makerspaces may lead to higher confidence and lower anxiety when conducting engineering design tasks, and that students with a high motivation to participate in engineering design were observed to be more likely involved in university makerspaces. These studies did not follow students as they progressed through the curriculum, and only provided the correlations noted in the data. This paper seeks to further explore the students demonstrating voluntary involvement during a single semester to determine the internal and external factors leading to makerspace use. This leads us to the following research question:

What factors influence a student's choice to spend time in a university makerspace?

Quantitative and qualitative methods are applied to investigate this research question. The quantitative study explores whether or not there are correlations between a freshman engineering graphics project requirements and student makerspace involvement. One hypothesis is that assigning a 3D modeling project requiring students to print their final design using makerspace equipment increases students' chances of becoming voluntarily involved in a makerspace.

In the freshman-level engineering design course included in the longitudinal study, one of the projects involves designing a product and creating a model using computer-aided design (CAD) software. Every student who takes this course is assigned this project; however, the requirements of this project vary between the different instructors who teach the course. Some of the instructors require their students to use the 3D printers available in the makerspace to print test parts and final parts of their designs. Other professors have their students send files of their CAD model to a staff member who prints the entire class's parts in a single batch, eliminating the need for students to use the makerspace themselves. Still other professors do not require their students to print their designs at all. The differences between instructors are due to a limited number of available printers and instructor preferences. Resources are not available for all students to print themselves and only recently has a large capacity printer been available such that the technician could print all sections in batches. For the remainder of this paper, students will be sorted into one of three groups based on the requirements for their project:

- Self Print – students required to use makerspace equipment to print their models
- Group Print – students whose designs were printed for them as part of a batch print
- No Print – students whose project did not require the models to be 3D printed

The qualitative portion of the study seeks to further explore what is leading students to become voluntarily involved in the makerspace. Surveys provide a wealth of information and can be used to reach a large population; however, the questions that this study seeks to answer necessitates a deeper and more coherent understanding of how these students become voluntarily involved in a makerspace. Qualitative approaches allow us to understand open-ended questions such as:

- Why are students interested in the makerspace?
- Did voluntarily involved students seek out makerspaces when starting at the university?
- How did these students become voluntarily involved?

In order to gain answers to these questions, we implemented an interviewing approach with voluntarily involved female students.

Through in-depth phenomenologically based interviews, students would be able to provide their narratives of how they got involved in the makerspace while also being prompted to explore and expand on their narratives by the interviewer. The phenomenological interview process uses three ninety minute interviews and is designed to develop a level of comfort between the interviewer and the interviewee; this allows the interviewer to be able to elicit prior and current experiences as well as establish the meaning behind the experiences of a person as they pertain to a certain topic, in this case makerspaces and making activities [11]. The in-depth phenomenologically based interviewing process is based on the life-history interviewing [12], focused in-depth interviewing [13], and the three-series interview structure [14]. In this interviewing process, the interviews are left open and semi-structured to allow for more freedom and natural conversation between the interviewer and the participant, which is ideal in our work for trying to capture how these students become involved in makerspaces. To answer the main research question, we examined the interview data to understand if students sought out makerspaces upon entrance into the university, what drove participate in the makerspace, and how exposure to making aligns with their involvement.

Methodology

The methodological procedures for the longitudinal study and the phenomenologically based interviews are described in the following two subsections.

Study One: Longitudinal Surveys. The longitudinal data in this paper was collected over a three semester period from surveys conducted in a freshman-level engineering design course. The survey was conducted twice each semester, once at the beginning of the semester and again at the end of the semester, to observe how makerspace involvement changed while the students were in the freshman engineering design course. Over three semesters, a total of 1,156 students completed both the pre-course and post-course surveys.

The survey consisted of three sections. The first section asked students about their involvement in university makerspaces following a brief makerspace description and examples of these spaces on campus. The first question in the section asked students if they had ever used equipment and/or resources available in a university makerspace. Students who claimed they had used this equipment were asked questions about their usage, including what activities they participated in and what kind of projects (class, personal, entrepreneurial, etc.) they worked on in the makerspace. These questions were used to determine the level of involvement for each student as further explained later in this section.

The second survey section consisted of the design self-efficacy survey developed by Carberry, Lee, and Ohland [15]. This survey asked students to rate themselves on four aspects when conducting engineering design:

- How <u>confident</u> they are to conduct engineering design.
- How <u>motivated</u> they are to conduct engineering design.
- How <u>successful</u> they would be conducting engineering design.
- How <u>anxious</u> they would be while conducting engineering design.

The final survey section collected demographic data including information about which section of the course each student was enrolled. This information helped determine which version of the final project the student was assigned: no print, group print, or self print.

The survey was conducted during the first week of the semester (pre-course) and the final full week of classes before the final exam period (post-course). In total, the survey took around 15 minutes to complete, for which the students were compensated with extra credit on a class assignment. The portion of the survey pertaining to involvement in a university makerspace was used to sort each participant into one of three groups based on work by Morocz, et al. [9]:

- No involvement, or student has not used any makerspace equipment and/or resources.
- Class-only involvement, or student makerspace use is only for class projects.
- Voluntary involvement, or student makerspace use beyond curricular requirements.

Using these definitions, 910 of the students were considered to have *no involvement* at the beginning of the freshman engineering course. The quantitative portion of this study focuses on these students and how their involvement levels changed after completing the course.

Study Two: Three-Series Interviews. Through purposive and snowball sampling, six females, all university makerspace users, participated in a three-series phenomenologically based interview process; future work will interview men. Through the three interviews, the participants are asked to: 1) relay their experiences with making prior to becoming involved in the makerspace, 2) describe their current making and makerspace experiences, and 3) reflect on their making and makerspace experiences. The interviews are each approximately ninety minutes in length based on the recommended length in the literature [14]. This interview structure was used to capture an accurate account of the students' making experiences throughout their life and if there was anything that led them to become involved in the makerspace.

To start the first interview, participants are asked to describe how they got involved in the makerspace. For the second interview, participants are asked to bring some things that they have made with them, talk about what they have made, and provide accounts of their making and makerspace experiences. In the third interview, participants are tasked with drawing out a timeline of their making experiences and are asked to reflect on these experiences. All interviews are open and semi-structured with questions to help guide the conversation if and when the interviewer needed to engage the participant.

Interviews were set up based on the participants' availability. The interviews for all participants occurred over the span of two months (with the exception of one participant having to reschedule to after the winter break). After each interview, the audio files were transcribed by an external company. Each transcription was edited by the interviewer while the interviewer listened to the audio files to ensure transcription accuracy in the language and terms. The interview process resulted in over 450 pages of transcriptions, and in this paper, transcriptions for each participant's first interview, equaling 166 pages of transcriptions, are the focus. From this first interview, we are able to extract how each participant got involved in the makerspace as well as develop infographics to analyze the participants' previous making and makerspace experiences.

Results

The results for the longitudinal study and the phenomenologically based interviews are separated into the two following subsections.

Study One: Longitudinal Quantitative. Table 1 shows the number of initially low scoring students from each group and the percentage of those students who ended the semester with no involvement, class-only involvement, and voluntary involvement. Based on a typical class size of 45 students, the Self Print classes would have 18 students use the makerspace for more than just class projects, whereas there is only 10 and 9 students from the Group Print and No print classes, respectively. To evaluate if these proportions were significantly different, a Chi-Squared test for association was run between each group, and a correlation was found between the project requirements and the likelihood of becoming involved (χ^2=17.6, N=689, df=2, $p<0.01$). To further evaluate how the project requirements impacted involvement, an N-1 Chi-Squared test was used [16] for *post hoc* analysis of each pair. As the Self Print version of the project required students to use the makerspace equipment, only students who moved from no involvement to voluntary involvement were considered "successes" for each N-1 Chi-Squared test; this indicates that the student used makerspace equipment and/or resources for more than just the class project. Comparing the Self Print students to the Group Print students showed a statistically significant difference (χ^2=11.5, N=417, df=1, p<0.01) and a small-to-moderate effect size (r=0.17). Similarly, comparing the Self Print students to the No Print students also showed a statistically significant difference (χ^2=16.3, N=395, df=1, p<0.01) and a small-to-moderate effect size (r=0.20). Finally, comparing the Group Print students to the No Print students did not show a statistically significant difference (χ^2=0.735, N=566, df=1, p=0.39) with no practical effect (r=0.04).

These results show that requiring students to use the makerspace as a part of a freshman engineering design class project had a statistically significant impact on the proportion of students from the class who also choose to use the makerspace for noncurricular projects. Students required to print their 3D models themselves were 81% more likely to become involved in the makerspace compared to those who were not required to print their parts.

Table 1. Breakdown of Students Initially Not Involved by Project Requirement

Project Requirement	Total of Students with No Previous Makerspace Involvement	Percentage of Students at Each Involvement Level at the End of the Course		
		No Involvement	Class-only Involvement	Voluntary Involvement
Self Print	123	13.0%	44.7%	42.3%
Group Print	294	59.2%	15.3%	25.5%
No Print	272	66.2%	11.4%	22.4%

As previous studies found that students who had higher motivation to conduct design may be more likely to become highly involved in a makerspace [9, 10], students' motivation to conduct engineering design at the beginning of the semester was also investigated. A comparison between students who ended the semester with Voluntary Involvement to those who ended the semester with No Involvement or Class-only Involvement in provided as Figure 1. No Involvement and Class-only Involvement are combined in Figure 1 to alleviate the potential bias resulting from the Self Print project's mandatory use of makerspace equipment.

To investigate if students' motivation to conduct engineering design was correlated to their involvement at the end of the semester, a t-test was used. This test revealed a statistically significant difference between the motivation scores of the students who became voluntarily involved (Voluntary) and those who did not (No Involvement or Class-only Involvement) (t=3.30, df=687, p<0.01) with a small-to-moderate effect size (d=0.24). This indicates that students with higher motivation to conduct engineering design are more likely to become voluntarily involved in a makerspace.

To further understand the impact that the different requirements for the modeling project have on students becoming involved in the makerspace, students of each version of the project were separately assessed in the same way, as seen in Figure 2. For the students who were required to print their models themselves (Self Print), a significant difference was <u>not</u> found between students who became voluntarily involved and those who did not (t = 1.33, df=149, p=0.19), although a small-to-moderate effect size was observed (d=0.22). For students who had their models printed for them (Group Print), a significant difference at α=0.05 was found between students who became voluntarily involved and those who did not (t=2.00, df=383, p=0.046) with a small-to-moderate effect size (d=0.25). For students who were not required to print their models (No Print), a significant difference at α=0.10 was found between students who became voluntarily involved and those who did not (t=1.91, df=372, p=0.057) with a small-to-moderate effect size (d=0.25).

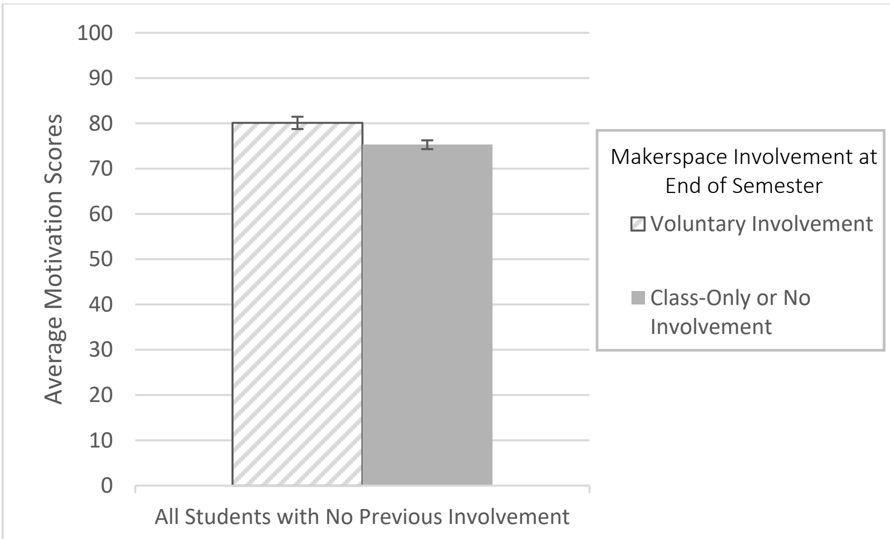

Figure 1. Comparison of average motivation scores and standard error of all students with low initial involvement in the makerspace based on their involvement at the end of the semester

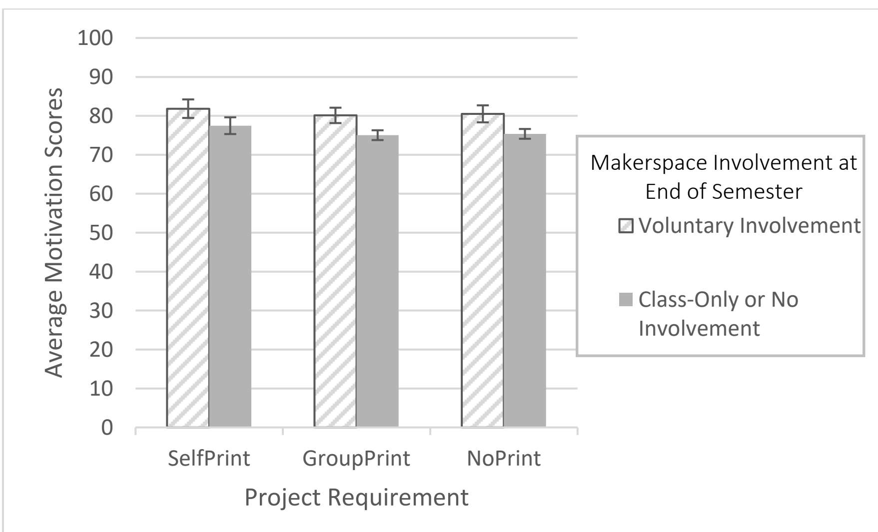

Figure 2. Comparison of average motivation scores and standard error of students with low initial involvement in the makerspace based on their involvement at the end of the semester and their project requirements

These results suggest that students with higher motivation to conduct engineering design are more likely to become voluntarily involved in a university makerspace; however, requiring students to complete a project using equipment available in a makerspace helps students with lower motivation to conduct engineering design to become more involved in university makerspaces.

Study Two: Three-Series Interviews. The interview data provides a way to gather a more in-depth understanding of the motivation behind a person's involvement in the makerspace. It is important to note that the interviewer did not explicitly ask any questions that were a part of the survey. Rather, the interviewer started with questions that were open-ended. From the students' responses, the researchers were able to identify how the different participants compared via exposure to the makerspace, involvement, and motivation. To directly determine if students who were highly motivated (as per terms of Study One) became voluntarily involved, three questions were asked regarding the participants' experiences: 1) once at [University], did you [the participant] seek out places to be hands-on, 2) once at [University], did you [the participant] seek out a makerspace, and 3) what really brought you [the participant] into the space? And, each of the participants' responses were analyzed to answer these aforementioned questions.

The purpose of the first question is to dictate whether a student was actively seeking out a place (makerspace or not) where they could build something. This question is complemented with the responses to the second question, where the participants are evaluated to determine if they actively seek out a makerspace as a place to be hands-on. The third question focuses on what caused the participant to become an active user in the makerspace. Each of the six interview participants are color coded (red, green, blue, orange, magenta, and gold), and the breakdown of these responses to these three questions is provided as Table 2.

Table 2. Selected questions and responses from students

Once at [University], did you seek out places to be hands-on?			
Red:	No	Orange:	Yes
Green:	Yes	Magenta:	No
Blue:	No	Gold:	Yes
Once at [University], did you seek out a makerspace?			
Red:	No	Orange:	Kind of
Green:	No	Magenta:	No
Blue:	No	Gold:	No
What REALLY brought you into the space?			
Red:	Class	Orange:	Major
Green:	Friend	Magenta:	Class + Friends
Blue:	Friend	Gold:	Friend

There is more to the motivation and involvement for these students. Were these women involved in making activities prior to being in these makerspaces? What was their exposure like before college? How does one female (Orange) choose her major specifically because it was highly hands-on? In order to get a better grasp on these questions and the motivation-involvement interplay, infographics were developed for the females' narratives, Figure 3. These infographics demonstrate each participant's involvement in and exposure to making activities. A key to the infographics follows in Figure 4.

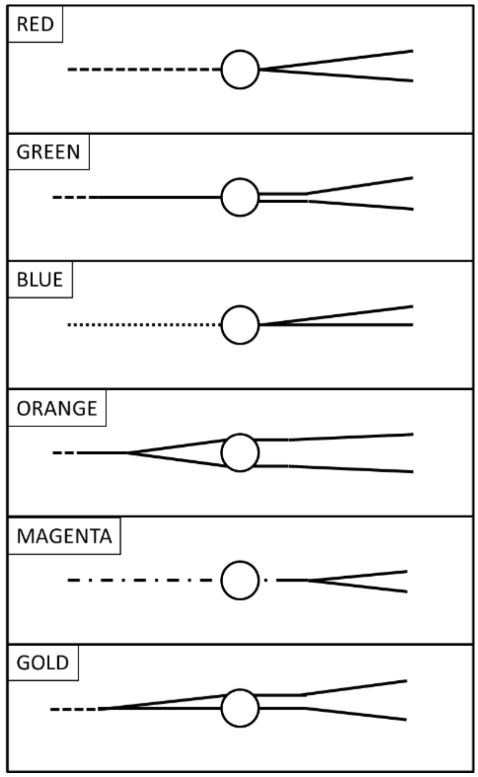

Figure 3. Infographics of participant exposure and involvement in making activities

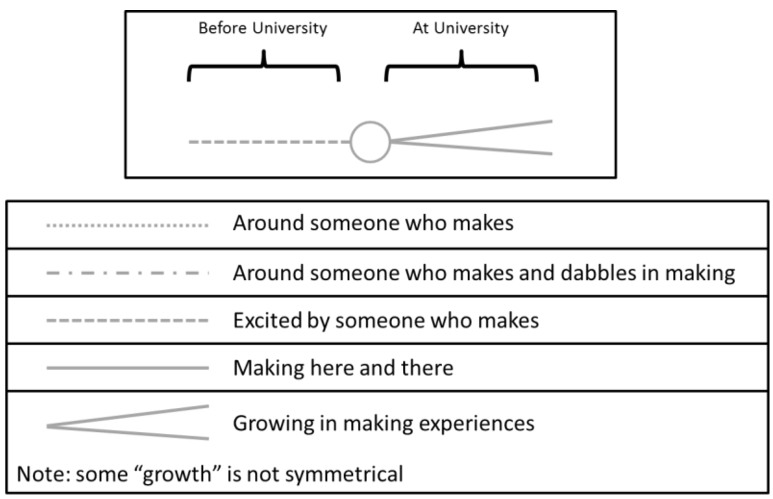

Figure 4. Key to infographics in Figure 3

Before University, Red is excited by the making experiences of others. This is extracted through her constantly wanting to be around her cousin when he is fixing or making something. She enjoys being around someone fixing a device and talks about how she is always asking question after question about what that person was doing; however, she does not discuss any instances where she makes something herself. She makes it a point to say that her making experiences started once she came to the university and really took roots during a specific design course. From there, she was hooked and decided to become more involved in the space. The knack for asking questions allows her to gain an overall well-formed knowledge of all the equipment in the space.

For Green, the narrative starts out the same. She is around someone who makes and is excited by the making; however, she starts taking on making activities before attending university. Once she gets to university, she begins promptly by seeking out a place to do hands-on activities. Eventually, a friend brings her into a makerspace and she immediately dives in so as to become more involved. Throughout this involvement, she builds basic proficiency in the machines, but does gravitate towards some more than others.

Blue has exposure to making throughout growing up and before attending university. Her father has been making things for the house and basically reconstructing the whole house. This was not something that she was excited about. Even when she comes to university, she does not intend to look for a place to make and build. Eventually, though, a friend invites her to the makerspace, and after spending time watching her friend make, she begins making things herself. Her desire to make things is very focused on a specific tool, even though she does understand how to use other machines.

Throughout Orange's youth, she was frequently exposed to making and took on making activities which grew her experiences. She realized that she needed and wanted to have a hands-on component be very integrated into her college major of choice. She selected a major that would be hands-on while also developing her design skills. She is constantly making something, day in and day out.

Before university, Magenta had exposure to making and dabbles in making activities here and there, but it is not anything that she would seek out in college. Through a class, though, Magenta encounters making activities and realizes that she enjoys learning through making. This is further developed by her friends inviting her to join them in their makerspaces, whether to build or to study. This causes her to be involved in making across the different makerspaces on campus.

Gold starts off with exposure to making from her father who introduces her to building-blocks which sparks her involvement in making. While her making experience before university are mostly computer-based making, she seeks out places and classes where she can make, gets introduced to 3D printers, and then eventually gets involved in the makerspace through a friend's introduction. From there, she gets more involved via taking on more responsibilities in the space and learning more about the machines.

Overall, there is not a single story that generalizes the different narratives of these females. Yet, the end result is their being voluntarily involved in the space. Whether they came in searching for ways to be creative hands-on (Green, Orange, and Gold) or hands-on making was not on their radar (Red, Blue, Magenta), they all become engaged and involved in these spaces. Yet, all but one (Orange) needed the extra push from class or friends to actually become involved in the makerspace. While they may talk of failures and discouragements in the space, they continue to come back and become even more motivated to keep doing hands-on design work.

Discussion

Previous studies [9, 10] have found involvement in makerspaces may improve confidence and reduce anxiety when completing engineering design tasks. The quantitative results of this study show that freshman-level students who had previously never used equipment available to them in a makerspace are 81% more likely to use makerspace equipment outside of class requirements if given an assignment that requires them to use the equipment. These findings make logical sense as requiring students to use the space will raise students' awareness of the resources available in the makerspace, may break barriers to first entry, and may increase students' comfort levels with the makerspace.

It was also previously found that motivation to conduct engineering design tasks may lead students to become voluntarily involved in a makerspace [10]. The results presented in Figure 1 and Figure 2 support this hypothesis, especially for students who are not required to use the makerspace equipment for their course project; however, for students required to use the space for a class project, no significant difference was found in the initial motivation to conduct engineering design tasks between students who became voluntarily involved later in the semester and those who did not become voluntarily involved. This may suggest that requiring students to use the equipment available to them in a makerspace helps students with lower motivation to conduct engineering design become more involved in a makerspace community. This also makes logical sense as it helps students overcome the barrier of using the space for the first time by requiring the students to do something they may not have the motivation to do themselves.

In the three-series interview study, the women are highly involved in the makerspaces. Their backgrounds differ, yet all become voluntarily involved in the makerspace. While all but one are intentional with seeking out a makerspace, they have all found their way to the makerspace, whether through friends or class. This reaffirms our findings from the longitudinal study, where class was beneficial in helping students to become involved in the makerspace. The students are able to see that they can build and make things with their hands while also becoming more motivated to do these engineering design tasks. We also see that three of the female students were invested in trying to design with their hands upon college entrance. For these women, finding the makerspace provided them with the opportunity to design and build with their hands in ways that they did not have exposure to before college. The other three females did not seek out hands-on design outlets, but they end up becoming voluntarily involved in the space because they are exposed, through class or their friends, to what they can do with the makerspace. This affirms that encouraging and perhaps requiring students to use the makerspace can help the students who didn't seek out the space (lower motivation to conduct engineering design) to become involved.

Future Work

Through the longitudinal study, students from freshmen-level entry classes are participating in the same three surveys in the sophomore and senior design classes. Future work will look to determine if the students who were voluntarily involved after their freshmen design course retain or increase their level of involvement as they progress through the engineering curriculum. From this, we will be able to gain more insights into the impacts that the curriculum may have on student involvement and who are the students who are staying involved in the space. Additionally, we will consider that the sophomore level design class requires extensive student use of equipment available in the makerspace. It is uncertain how this class will impact student involvement and self-efficacy; this will be explored in future work. In juxtaposition to qualitative data, more interviews will be conducted with men, and comparisons between the student narratives and involvement infographics will be investigated

One limitation of the longitudinal quantitative data were the different requirements for the course project as given by different professors. Therefore, the differences observed the proportion of students choosing to us the makerspace for more than only class project could be a result of the professor teaching the course. Future studies will include observations of differing project requirements given to classes taught by the same professor.

Conclusions

University makerspaces have the equipment for students to design, but the students also need to be motivated and inspired to actually use these makerspaces for designing. Fostering this motivation remains a challenge in the educational setting as professors want to encourage use of the space without negating the maker mindset nor causing students to resent designing and making as a result of a class-enforced project. In a freshmen-level engineering design course, students were sorted into three groups based on project requirements for a 3D modeling/printing assignment (self print, group print, no print) and further examined for their engineering design self-efficacy and involvement in the makerspace. It was found that students who were exposed to the makerspace via the classroom were more likely to be voluntarily involved by the end of the semester; even students with initially low motivation to conduct engineering design followed this trend.

The self-efficacy findings are comparable to the findings from the phenomenologically based interviews of female students who are each voluntarily involved in the makerspace. The female users were introduced to the space through both friends and class, and given that the interviewees were split 50/50 with seeking out hands-on making activities upon starting their undergraduate, this reaffirms that initial motivation does not impact involvement in the space as strongly as being presented an initial opportunity to use the space. It seems that student involvement in the makerspace is more impacted by the engineering design curriculum and their exposure to the space. Engineering design curriculum does not necessarily have to enforce strict use of the space, but rather a cohesive and open exposure to the space allows the students the ability to see their potential to design and create in a makerspace.

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