Makerspace Involvement and Academic Success in Mechanical Engineering

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***Abstract*— This Full Research paper presents a study to determine the correlations between student involvement in an academic makerspace and academic achievement as measured by GPA. University makerspaces are open environments designed to encourage creative collaborations and innovative exploration by providing students access to a variety of machines and tools typically focused on rapid prototyping. In an effort to understand the benefits these spaces in academia, there have been several studies on their founding and facilitation; however, there is a lack of data-driven studies of student involvement and the impact of makerspace use on student development.**

This paper presents preliminary results from an investigation to so show the impact of involvement in an academic makerspace on GPA. By measuring cohorts of students at different stages in the mechanical engineering curriculum, correlations are made between the level of involvement in makerspaces and GPA. The results indicate that students who use the space to build and create, either by choice or for a course requirement, have been shown to have a higher average in-major GPA than students who do not use the space. These findings and more encourage the further exploration of the impact of makerspaces through both quantitative and qualitative methods.

Keywords—makerspaces, involvement, academic performance

I. Introduction

The opportunity to create, invent, and innovate is crucial to the development of engineers [1]. Makerspaces provide an opportunity for students to gain these experiences through access to machinery, tools, and spaces dedicated to the creation of prototypes. Makerspaces also provide opportunities for students in technical programs to improve the communication of their designs, especially to students outside of technical programs [2]. These experiences allow students to go through the trial and error process necessary to develop a better understanding of the design process [3]. For all of these reasons and several others, makerspaces on university campuses have increased by more than ten-fold in the last decade [4].

As with any new trend in education, there have been several studies into makerspaces, their development, and their impact on the students who use them [5][6][7][8]. Through investigation of several spaces, Barrett et al., [5] discovered that the majority of these spaces are housed by engineering colleges, but are still largely available to students outside of engineering degree programs. Many studies have attempted to discern best practices for establishing and running successful academic makerspaces. Some of the findings include observations of optimal staff-to-user ratios and floor space-to-user ratios [6], sustainable faculty leadership to nurture student learning [7], and the establishment of a culture conducive to innovation [8]. While all of these factors are important for understanding how to best establish academic makerspaces, there has been a lack of studies that use empirical data to show the effects these spaces have on the students who use them [9]. This paper presents preliminary data investigating how students who use the space are impacted in terms of their grade point average (GPA) and design self-efficacy. This is part of a large, multi-year, collaborative study between three universities that aspires to evaluate the impact of makerspaces on factors such as retention in a degree program, degree completion, GPA, the ability to generate solutions for open-ended problems, and self-efficacy in conducting engineering design tasks. While the data presented in this paper are preliminary, these preliminary results do show positive correlations for students involved in university makerspaces and the students' ability to succeed in engineering coursework.

II. Methodology

Students in three different courses completed a survey that included questions about the students' demographics and use of academic makerspaces. The three courses were a freshman-level introduction to engineering graphics course, a sophomore-level design course, and a senior-level capstone course. These courses were chosen as data-collections points because they are required courses in the mechanical engineering curriculum, must be taken in the order listed, and are typically mostly taken by mechanical engineeering students. The students in these courses, therefore, provide a generalizable sample of the mechanical engineering student body, and the student's class where data collection occured indicates where each student is in the mechanical engineering curriculum. The students are, thus, identified at freshmen, sophomores, or seniors based on the course they were taking when they completed the survey; it should be noted that while this may not be the student's class by credit, but it is their class by placement in the mechanical engineering curriculum. Within the freshman course, there are transfer students.

In each course, the survey asks various questions about use of academic makerspaces. After an explanation of what a makerspace entails and a few example spaces the students may be familiar with, the initial question for this portion of the survey asked if the student had ever used equipment available to them in an academic makerspace. If the students answered "yes", they were asked several questions regarding the types of activities they conducted in the space, the types of projects worked on in the space, and an estimate of the amount of time spent in the space. For further evaluations, each participant was sorted into one of three groups based on their responses to the survey concerning level of involvement within a university makerspace. These three groups are listed here with brief definitions:

- **No Involvement** – Students who have never used makerspace equipment or resources
- **Class-Only Involvement** – Students who have only used makerspace equipment for class projects
- **Voluntary Involvement** – Students who chose to use makerspace equipment for projects other than class projects (e.g., personal projects, entrepreneurial projects, etc.).

After each student's involvement group was determined, the students were listed in a spreadsheet along with demographics and university identification numbers. This spreadsheet was sent to a university administrator, who used the identification numbers to add the cumulative and major GPAs for each student. Major GPAs were calculated using only grades from courses in the mechanical engineering department. The registrar then removed the identifiers, randomized the order of the students, and returned the spreadsheet to the researchers. This allowed the researchers to compare the GPAs of each student with other factors such as their involvement level in academic makerspaces without being able to identify the GPA data of any particular student.

To evaluate the impact of involvement in academic makerspaces on students, the GPAs from students in each involvement group were evaluated using a two-way ANOVA with blocking based on classification (freshman, sophomore, or senior). Including the blocking based on classification helps to eliminate the innate variability present between students at different points in an engineering curriculum. GPAs tend to decrease freshman to senior, and students have more opportunity to become involved in makerspaces the longer they have been at the university. For ANOVA tests that indicated significant differences between at least two groups, Fisher's Least Significant Difference (LSD) was used to evaluate differences between pairs. Effect sizes were also calculated and evaluated using Cohen's rule-of-thumb [10]. Both the cumulative GPA and in-major GPA of students were evaluated using this method, and the residuals of the tests were evaluated to confirm the assumptions of normality, equal variances, and independence held true. The data presented in this paper was collected through a protocol approved by the university's Internal Review Board (IRB).

III. Results and Analyses

A. Prelimary Data-Design Self-Efficacy

Initial analyses of the longitudinal data have found correlations between involvement in academic makerspaces and engineering design self-efficacy. This data was gathered and analyzed using a previously established survey metric where students rated themselves through the following four lenses of self-efficacy for conducting engineering design tasks: confidence, motivation, expectation of success, and anxiety [11]. At multiple universities, students who choose to use the makerspace have been found to have higher confidence and lower anxiety while completing engineering design tasks than students who have not used an academic makerspace [12, 13]. Another previous preliminary analysis found that student involvement in academic makerspaces can be influenced by requiring students to print theirs parts in the makerspace. In an introductory engineering graphics course, requiring the students to use makerspace equipment for a small portion of a class project more than doubles the probability that a student will choose to spend time in the makerspace [14]. Combining these results shows how a relatively simple change to the requirements of a course project can impact students' engineering design self-efficacy.

Additionally, the direct impact of makerspace use was supported through the observation of freshman students over the timespan of one semester [15]. The engineering design self-efficacy scores at the beginning and end of the semester for freshmen in an introductory engineering graphics course were compared between students who still had not become involved by the end of the semester (Never Involved), students who initially became involved between the two surveys (Became Involved), and students who were involved prior to the beginning of the semester (Always Involved). These scores can be seen in Fig. 1 and Fig. 2. It was observed that students who began the semester with no involvement, but became voluntarily involved during the semester, improved their confidence and expectation of success for conducting engineering design tasks significantly more than students who did not become involved. Interestingly, the motivation to conduct engineering design tasks did not significantly change from the beginning to the end of the semesters, leading researchers to believe that motivation may be a causal factor for students to become involved in an academic makerspace.

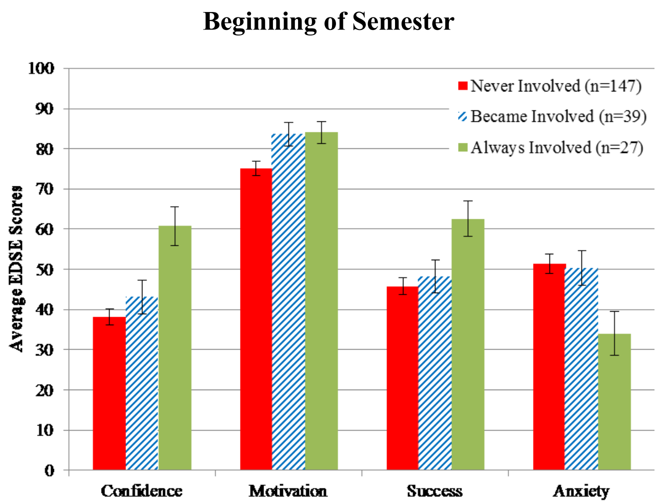

Figure 1. Average Engineering Design Self-Efficacy (EDSE) scores from beginning of course for each involvement change group, shown with ±1 standard error [15]

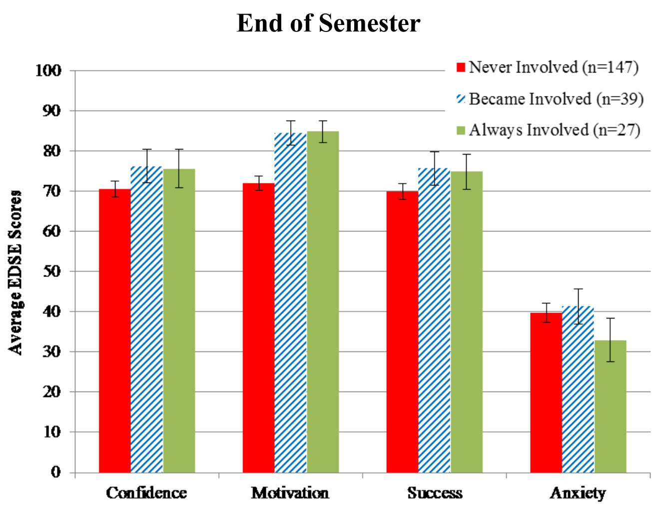

Figure 2. Average Engineering Design Self-Efficacy (EDSE) scores from end of the course for each involvement change group, shown with ±1 standard error [15]

These identified connections between makerspace involvement and engineering design self-efficacy demonstrate promise that makerspace involvement is beneficial to engineering students, additional work is needed to quantify the benefit in terms of an accepted measure of student success – GPA. The data and analyses presented in this paper explore the impact of academic makerspaces on GPA of students with varying levels of involvement in an academic makerspace to shed more light on how makerspaces may influence the academic achievements of engineering students.

B. Prelimary Data-Involvment and GPA

The survey was completed by a total of 211 students. However, since the data was collected from courses within the mechanical engineering department and the overall study focuses on students in this department, students with majors other than mechanical engineering were excluded from analysis. This left a total of 171 mechanical engineering students. The breakdown of students into class-level and involvement level can be seen in Table 1.

The average cumulative and major GPAs of the participants at each involvement level can be seen in Table 2. The ANOVA test for average cumulative GPA did not show a significant difference between the three involvement levels as seen by the ANOVA results shown in Table 3. The ANOVA test for average in-major GPA found a statistically significant difference existed between the three involvement levels with 90% confidence as seen by the ANOVA results shown in Table 4.

To determine significant differences between the groups, post-hoc investigation using Fischer's Least Significant Difference (LSD) evaluation with 90% confidence was conducted between pairs. These evaluations revealed a statistically significant difference between Voluntary Involvement students (M=3.40, SD=0.458, n=57) and No Involvement students (M=3.28, SD=0.617, n=74) with a small-to-moderate effect size (d=0.34). A significant difference was also found between Class-Only Involvement students (M=3.47, SD=0.578, n=40) and No Involvement students with a small-to-moderate effect size (d=0.37). There was no significant difference found between Voluntary Involvement Students and Class-Only Involvement students.

TABLE I. Number of participants at each involvement level

Progress in Curriculum	***No Involvement***	***Class-Only Involvement***	***Voluntary Involvement***
Freshman	60	30	27
Sophomore	5	5	6
Senior	9	5	24
Total	**74**	**40**	**57**

TABLE II. Average GPA based on makerspace involvement level

Involvement Level	***Average Cumulative GPA***	***Average Major GPA***
No Involvement	3.23	3.28
Class-Only Involvement	3.41	3.46
Voluntary Involvemet	3.34	3.40

TABLE III. Results of ANOVA on Cumulative GPA based on Level of Involvement with blocking of Class Level

Source of Variance	***df***	***SS***	***MS***	***F***	***p-value***
Involvement Level	2	0.947	0.47	2.15	0.120
Class Level	2	0.136	0.07	0.31	0.736
Error	166	36.63	0.22		
Total	170	37.62			

TABLE IV. Results of ANOVA on Major GPA based on Level of Involvement with blocking of Class Level

Source of Variance	***df***	***SS***	***MS***	***F***	***p-value***
Involvement Level	2	1.56	0.78	2.53	0.082†
Class Level	2	1.42	0.71	2.31	0.102
Error	166	51.16	0.31		
Total	170	53.67			
†Significant at α=0.10					

IV. Discussion

While students involved in makerspaces, either voluntarily or for a class assignment, perform better in their core classes (measured via in-major GPA) than students who do not use makerspace equipment, involvement level does not significantly affect overall GPA. Therefore, it would be expected that student involvement may improve performance in engineering courses, but may not improve performance in non-engineering courses.

To further investigate the impact of involvement in makerspaces on student performance in coursework, the histograms shown in Fig. 3 and Fig. 4 were created. In order to protect participant anonymity, only Freshman data is included in these histograms as including Sophomore or Senior data separately would have allowed for participant to be identified due to the smaller sample sizes. Some interesting trends noticed in the cumulative GPA histograms (Fig. 1) include a high percentage of voluntarily involved students in the highest GPA bracket, but the GPAs of the voluntarily involved students has a flatter distribution below the highest bracket. Similarly, the histograms of the major GPAs (Fig. 2) also show a flatter distribution for students who are voluntarily involved. This is contrary to the more bi-modal shape of the Class-Only Involvement group. These observations may indicate that increased involvement in the makerspace may help some students in gaining a better understanding of their coursework while hindering others. In order to gain a better understanding of what is causing these impacts, further studies will need to be completed.

V. Limitations and Future Works

The results shown in this study represent a cross-section of students in a mechanical engineering program. Therefore, while these results prove useful in drawing correlations between makerspace involvement and academic success, the results fail to indicate causation. It may be that students who excel in coursework may also possess a motivation to become more involved in an academic makerspace. In order to determine whether or not makerspace involvement has any impact on academic performance, students will need to be observed both before and after becoming involved in the space. This longitudinal approach should be implemented in future studies. The results of these studies would have the potential not only to determine causation between makerspace involvement and academic performance, but may also provide insight into what other factors may contribute to a student's likelihood of becoming involved in an academic makerspace. These quantitative results could also be examined more deeply through the inclusion of qualitative research methods to gain a better knowledge of what drives students to join the maker movement.

Another limitation of the results presented is the relatively small sample size of students at the sophomore and senior levels of the curriculum. Gaining data from additional students in these classifications would allow for a more in-depth study of when makerspace involvement may be most beneficial to students.

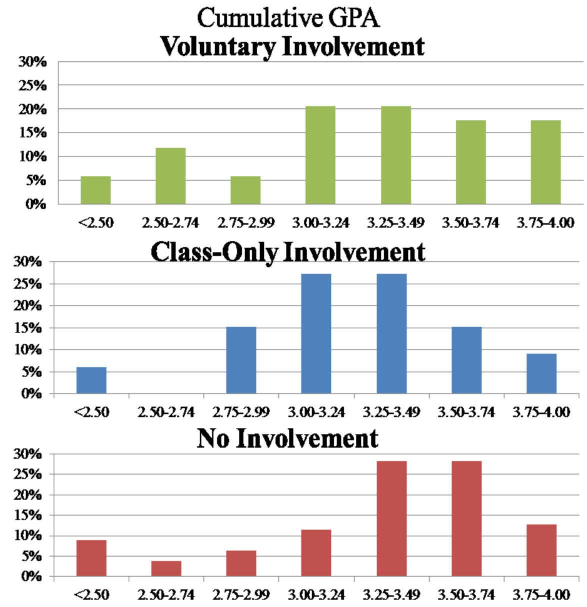

Figure 3. Histograms of Cumulative GPAs of Freshman-level students based on level of involvement in an academic makerspace.

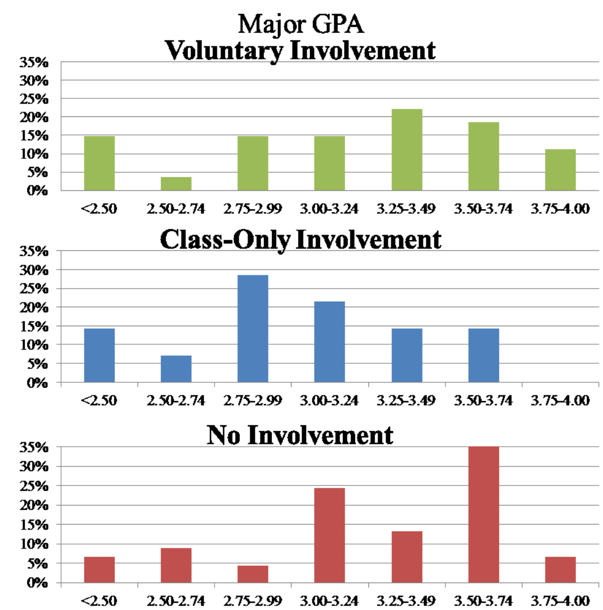

Figure 4. Histograms of Major GPAs of Freshman-level Students based on level of involvement in an academic makerspace.

Finally, the method presented in this paper for determining the makerspace involvement into three categories also limits the findings available in this study. Students who are voluntarily involved in the space could differ greatly in the amount of time spent in the space or the types of projects carried out in the space. While it is interesting to look at all students who use the space by their own choice, looking at these additional factors could be enlightening. Future studies should include ordinal or continuous data to evaluate a more thorough correlation between the level of involvement and factors such as academic success.

VI. Conclusions

As makerspaces continue to grow in popularity on university campuses, it is important to understand the impact these spaces have on the students who choose to spend time utilizing makerspaces resources. The study reported herein investigates the correlation of involvement in an academic makerspace with academic performance by examining the GPAs of students with varying levels of involvement. The study found that students who use the space either for class projects or for their own personal projects had significantly higher in-major GPAs than students who did not use the space. If the goal of instructors is to provide students with the best opportunity to succeed both in the classroom and beyond into careers, these results merit a deeper investigation into how we can increase the accessibility and effectiveness of academic makerspaces so that students can most effectively utilize the makerspace's resources. By increasing the accessibility of these spaces, we may be able to aide students in becoming more successful, well-rounded, and experienced engineers.

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