International Journal of Engineering Education Vol. 38, No. 6, pp. 1851–1861, 2022
Printed in Great Britain
0949-149X/91 $3.00+0.00

Predicting Success of Engineering Student Makers: Relationships Between Makerspace Involvement, Academic Performance, and Engineering Design Self-Efficacy*

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Makerspaces are common in engineering programs around the country and around the world. As universities invest more into these spaces, researchers investigate more the impacts of making in the educational setting. As more students across more educational contexts get involved in making and makerspaces, there is a greater need for educators to gain a more wholistic understanding of the impacts of making on the academic environment, both positive and negative. In this paper, we look at the critical relationship between makerspaces and academic performance at a unique university with a design-centric approach to engineering education. This study presents three key findings: First, more involvement in making early in the curriculum is related to increased retention. Second, increased anxiety towards engineering design is connected to both lower retention and lower involvement in academic makerspaces. Third, GPA and makerspace activity are largely independent at this university where the engineering curriculum prescribes engineering students' engagement in making. As impacts of academic makerspaces are unfolding before us, these findings shed a positive light on their contribution to engineering education.

Keywords: makerspaces; engineering design; engineering education; academic performance

1. Introduction

Makerspaces are hands-on learning environments equipped with making equipment ranging from digital prototyping to machining to sewing to electronics production and more. These spaces afford hands-on learning for not only making, but also, management, collaboration, and leadership [1]. Makerspaces continue to rise in popularity at universities all over the world creating opportunities for hands-on learning not possible in a traditional classroom. There are many studies published on academic makerspaces, but there is a large gap in empirical evidence describing the relationship between makerspaces and their impact on the student [2]. Previous research has shown that there is a positive correlation between makerspace involvement and engineering design self-efficacy; students that are more involved in making have a higher confidence, motivation, and expectation of success about engineering design activities [3, 4]. It has also been shown that there is a positive correlation between grade point average (GPA) and makerspace involvement [5]. Further understanding on the academic impacts is critical for universities moving forward as these spaces become more integrated into engineering education. This paper presents cross-sectional data from a five-year study examining relationships between makerspace involvement, engineering design self-efficacy (EDSE), and academic performance measured through GPA and retention in engineering. This study was conducted at a university with a uniquely design-centric engineering program. As a result, makerspaces are thoroughly integrated into their engineering curriculum, and all students have extensive exposure to making. This environment creates a rich opportunity to observe the impacts of makerspaces and provides this study with unique implications for makerspaces in engineering curriculums.

Hilton et al. [4] presented findings from the five-year study on the relationships between makerspace involvement and engineering design self-efficacy from three diverse universities including the uni-

* Accepted 20 June 2022.

versity in the current paper. Two universities in their paper, University A and C, are public institutions with more traditional engineering programs; University B, the focus of the current paper, has a more design centric engineering program. Hilton's analyses centered around examining makerspace involvement and categorized involvement at three use levels: no involvement, class-only involvement, and voluntary involvement. The analyses looked at differences across EDSE using the design self-efficacy instrument developed by Carberry et al. [6] which is comprised of four factors: confidence, motivation, expectation of success, and anxiety. At University A and C, Hilton et al. showed that students who are voluntarily involved (not class-related) in the makerspaces, have greater confidence, motivation, and expectation of success in completing design tasks and lower levels of anxiety for design tasks at one school. At University B, this same finding was absent with more design integrated throughout the curriculum [3, 7–9]. The differences between non-users and required users in confidence and anxiety show that required involvement may positively impact students' engineering design self-efficacy. The lack of significant differences between required users and voluntary users at a school with a design intensive curriculum likely suggests that required makerspace involvement has similar impacts to voluntary involvement, suggesting a lack of selection bias between required and voluntary uses. This evidence would support the inclusion of makerspace activities into the required curriculum. The Hilton et al. (2020) findings were not based on longitudinal student data, and consequently, were unable to evaluate the relationship between voluntary makerspace involvement, student GPA, Design Self-Efficacy, and student retention in engineering.

In an earlier paper, with a smaller cross-sectional dataset collected during this same 5-year longitudinal study, Hilton et al. [5] examined relationships between GPA and academic performance among mechanical engineering students at University C [5]. For these mechanical engineering students, Hilton et al. found a significant relationship between makerspace involvement and major-specific GPA, but no relationship between a makerspace involvement and overall GPA. Voluntary and class-only makers both showed higher GPAs than students who were not involved in making; however, no significant difference in GPA was found between voluntary and class-only makers. Their findings suggest that benefits found through making can be gained whether the makerspace activities are student driven or class driven. Further, when looking at the distribution of GPA among makers, they found that voluntary makers had a large concentration of students with very high GPAs and with very low GPAs. This finding suggests that makerspaces may benefit academic performance for some students but possibly detract for others.

The study presented herein is the first study presenting findings from the entire longitudinal dataset of the authors' five-year study; the data were collected at University B. The findings presented in this paper build on those of the previously described Hilton et al. [4, 5] publications, which were based on cross-sectional data from the five-year study. Findings presented in this paper provide greater insight into the relationship between making and GPA and introduces key findings between making and retention. Investigation of the longitudinal data revealed new relationships between EDSE and makerspace involvement; these relationships improve our understanding of the impact of prescribing making activities to engineering students.

2. Background

The promise and potential of learning in makerspaces has been advanced by those who study K-12 [10], museums and libraries [11], engineering education [12, 13] among others, and the interest is international [14, 15]. Makerspaces offer opportunities for self-driven learning, creative thinking from building models, creating art, and visualizing ideas [16] providing students with a means to develop creativity, curiosity, independence, determination, and grit [17–20]. Makerspaces provide opportunities for collaboration, discovery, and innovation [21], where ideas, tools, machines, and knowledge are shared amidst the use of advanced technologies and the making of projects [22, 23]. This type of collaborative learning environment is believed to be the next generation classroom [24], and the ultimate bridge between university and industry for STEM-related fields [23]. Perhaps even more revolutionary, the learning promoted in makerspaces is seemingly compatible with the learning most needed by students with learning challenges [25].

As making and makerspaces have become more prevalent, especially in educational settings, there has been a push to gain a greater understanding of how different universities have established and managed their spaces. Barrett et al. [26] conducted a passive internet search of dozens of makerspaces to see what their websites claimed about their spaces. Wilczynski [27] conducted a more targeted survey of known academic makerspaces to determine what access requirements, available equipment, and funding strategies were being used in American makerspaces. Leaders of some of these makerspaces were also interviewed by Tomko et al. [28] to determine common themes necessary for a successful makerspace.

Further, Tomko et al. conducted a set of qualitative studies using in-depth interviews and ethnographic methodologies to identify *what* and *how* students are learning in makerspaces, the multiple pathways into makerspaces, and the socialization of novice engineering students in making centered curricula [29, 30]. Phenomenological interviews were used to develop a comprehensive typology of learning happening in makerspaces. The typology describes the modes of learning, as well as the cognitive, interpersonal, and intrapersonal proficiencies developed in makerspaces [1, 31]. Trends in the pathways of women students into makerspace communities were identified, and three common characteristics emerged: (1) recurring catalysts; (2) immersive opportunities; and (3) affirming encounters [1, 29]. Tomko et al. found that makerspace engagement develops students' intellectual, interpersonal, and intrapersonal knowledge and skills. Students engaging in makerspaces develop a deeper understanding of their engineering course work with an increased motivation to learn, and makerspace users develop a shared sense of belonging [13].

Makerspaces are also argued by Wilczynski et al. [32] and Wigner et al. [33] as an investment that may aid engineering programs in their accreditation through the Accreditation Board for Engineering and Technology (ABET), helping to fulfill General Criteria 7 [32], "Modern tools, equipment, computing resources, and laboratories appropriate to the program must be available, accessible, and systematically maintained and upgraded to enable students to attain the student outcomes and to support program needs" [34]. Wigner et al. [33] demonstrate through student interviews that academic makerspace engagement allows many engineering students to achieve ABET student learning outcomes with Outcome 4, "an ability to communicate effectively with a range of audiences" [34] and Outcome 7, "an ability to acquire and apply new knowledge as needed, using appropriate learning strategies" [34] being the two highest rated outcomes.

The impact of makerspaces on student learning is not well documented or known. In a recent review of literature published through the *American Society for Engineering Education*, Weiner et al [35] found that just 5 out of 68 papers "made explicit and repeated references to Learning Sciences concepts, terminology, or theoretical frameworks" (pp. 9–10) Furthermore, Rosenbaum and Hartmann [36] found that there is an increasing number of publications on making, makers, and makerspaces, indicating a growing awareness in the lack of empirically-driven studies investigating makerspace impact. Their findings suggest that significant work is still required to understand just how academically housed makerspaces impact students' education. The current study evaluates retention, GPA, makerspaces involvement and demographics to further this understanding.

3. Methodology

This paper presents cross-sectional results from a five-year longitudinal study. Students were tracked through courses in an engineering degree program and surveyed about their involvement in university makerspaces and their engineering design self-efficacy. With the students' consent, academic performance data was obtained on GPA, standardized test scores, and retention. One of the most unique aspects of this study is the university at which these data were collected. This research was conducted at a large, primarily liberal arts college in the mid-Atlantic United States. This engineering program takes a unique approach to engineering education through a design-centric curriculum. Making, and consequently, making spaces are integrated within the curriculum through engineering design courses in all four academic years. These curricular features make this a unique engineering student population for studying the impact of making involvement on academic performance and engineering design self-efficacy. This section will discuss the university and its unique engineering program in more detail, the study participants, the survey and its components, and how the survey was used.

3.1 University Context

The results presented herein are based upon data collected from students completing an engineering degree at a design-oriented engineering program at a medium-sized university in the mid-Atlantic region of the United States. This program graduates students with a B.S. in Engineering without specialization; specialization occurs through a mentored two-year engineering project experience beginning students' junior year. At the core of the engineering program are six sequential engineering design courses taken from sophomore year to senior year, covering the design process and commonly used design tools and methodologies. This engineering design curriculum is complemented by two hands-on design projects: (1) a two-semester, client-based engineering project with a community or industry sponsor during the sophomore year (e.g., building human-powered vehicles for individuals with needs uniquely different from those of the students') and (2) the aforementioned, two-year mentored engineering project, in which students work on traditional design-build projects, competition teams, industry sponsored-projects, or entrepreneurial ventures. During the sophomore design courses, students learn and apply tools such as interviewing, persona development, functional modeling, requirements generation and validation, benchmarking, design conceptualization and evaluation, prototyping and experimentation, applied analytical and geometric modeling (using MATLAB and SolidWorks), bill of materials, testing and refinement, and technical reporting (oral and written). During the junior and senior year design courses, students work with mentors to develop connections between engineering science course content and new materials necessary for project success, and students deep dive into additional engineering design topics such as TRIZ and Design for X.

Through this concurrent class and project-based curriculum, students are guided through each stage of the design process as they design their own tangible projects. Many projects are fundamentally intertwined with the engineering program's makerspaces and fabrication labs, resulting in students frequently engaging in these spaces to create prototypes, design and run experiments, and manufacture solutions. Many of these engineering design projects also make use of the student-accessible machine shop; students apprentice with the machinist to refine their designs and manufacture parts they otherwise could not with conventional makerspace tooling.

In addition to this explicit design curriculum and its respective projects, the courses in this program often take advantage of these spaces, incorporating activities like heat-treating steel, casting-concrete, and testing student-designed circuitry into the conventional class content. Beyond the classroom, students are permitted to pursue their own personal interests in these spaces as well, though admittedly these "super users" represent just a small, but very visible portion of the overall engineering student population. As a result of this class and personal use, the making spaces, design studios, and fabrication labs in this program serve as both an academic and social hub where students can learn, collaborate, and tinker.

3.2 Participants

Students were recruited to participate through four required courses progressing through the engineering curriculum. Two cohorts of students were surveyed over this four-year period with the cohorts staggered by one year. This paper focuses on the data from the final three academic years: sophomore, junior, and senior. First year students were not surveyed about their makerspace involvement because the survey was administered near the beginning of the academic year and the students had not had much chance to be involved. Because this study was longitudinal in nature some students participated in multiple academic years. This paper presents cross-sectional results from these three groups of students. These data represent surveys completed by 123 sophomores, 97 juniors, and 57 seniors. Of the participants, 128 identified as male, 41 as female, and 5 either identified as other or preferred not to disclose.

3.3 Survey

Information was gathered regarding engineering design self-efficacy, makerspace involvement, academic performance, and demographics. Through a survey, students self-reported information about engineering design self-efficacy, makerspace involvement, and demographics. Academic performance data were collected directly from the school records with students' consent.

Students' design self-efficacy was surveyed using the Engineering Design Self-Efficacy (EDSE) instrument, a validated measure from Carberry et al. [37]. The EDSE is a 36-item instrument that measures four dimensions of self-efficacy regarding engineering design activities: confidence, motivation, expectation of success, and anxiety. Students' respond to 9 questions on each dimension on a scale from 0 to 100 incremented by 10s. For this paper, each dimension of the EDSE is analyzed separately taking an average of the responses to the nine questions for each. Previous research on the relationship between the EDSE and makerspace involvement was outlined in the introduction [4].

Makerspace involvement was measured through a series of questions developed specifically to understand student engagement in making activities on campus. Students were asked about projects, use of making equipment and software, and how they interacted with making in their degrees. In this paper, two questions are the focus of the analysis:

1. Since starting in the engineering program, which of the following equipment have you used when working to complete engineering design projects?
2. Since starting in the engineering program, have you had experience with equipment and/or engineering design software outside of the program's curriculum? If yes, briefly describe which equipment and/or engineering design software and where the experience occurred.

For the first question, participants were shown a list of 11 types of making equipment to choose from: 3D printer, laser cutter, water jet cutter, CNC machines, soldering or welding equipment,

Table 1. Guidelines for determining elective or prescribed makers from responses to the maker survey

Makerspace Elective Involvement Guidelines	
Elective	**Prescribed**
Lists personal project experience.	Only lists course project experience.
Lists elective research project experience.	Only lists pre-college/high school experience.
Lists making equipment beyond what is taught in class.	Only lists making equipment taught in class.
Lists extracurricular club involved in making.	Only lists engineering software (e.g., CAD, MATLAB, etc.).

mill, lathe, drill press, table saw, handheld power tools, and basic tools (e.g., screwdriver, hammer, etc.). Students were also given the option of none, and if students wanted to add equipment that was not on the list, the option was also available. Students selected all options that applied to them. For analysis, a count of all equipment was used as a measure of the depth of students' experience with making. For the second question, students replied with a yes or no and then a text response clarifying their involvement. For analysis, these two questions were used to classify students as *elective makers* if they were involved in extracurricular making activities or *prescribed makers* if they were not. If the student responded yes and described an activity with making equipment outside of a classroom or a class project they were classified as an elective maker. Table 1 lists the coding rules to determine if students were described as elective or prescribed makers.

Students' academic performance measures were gathered through the university with the students' consent. Academic performance was evaluated on GPA, standardized test scores, and retention within the university degree program. For analysis, cumulative GPA from the respective academic year is used for the analyses conducted within that academic year of the cross-sectional study. For example, when analyzing relationships between GPA and makerspace use between sophomores, sophomore cumulative GPA will be used as the measure of academic performance.

4. Results

This section presents the relationships that were found between makerspace involvement, EDSE, academic performance, and demographic factors. Makerspace involvement was measured in two ways as outlined in the previous section: with a count of different types of making equipment students had used and a classification of students as prescribed makers or elective makers. EDSE is measured by four independent dimensions: confidence, motivation, expectation of success, and anxiety. Academic performance was measured using retention, GPA, and SAT math and verbal scores. Three demographic factors were analyzed: gender, race as underrepresented minority status, and first-generation college student status.

4.1 Retention

The first analyses focus on retention comparing mean scores between students that stayed in the engineering program to those that did not. All juniors and seniors who participated in the study were retained. Of the 123 sophomore students that participated in the study, 18 (14.6%) were not retained in the degree program. We first analyzed retention on other measures of academic performance. There was a significant difference in GPA between those that were retained and those that were not t = –3.633 (df = 83, $p < 0.001$). Sophomores who were retained showed significantly higher GPAs (M = 2.88, SD = 0.42, n = 78) than those that were not (M = 2.27, SD = 0.42, n = 7). There was also a significant difference across retention in SAT math test scores, t = –1.996 (df = 140, $p < 0.05$) with those that were retained showing significantly higher scores (M = 607, SD = 63, n = 130) than those that were not (M = 568, SD, n = 12). However, there was no difference in SAT verbal test scores (t = 0.271, df = 140, p = 0.787) between those that were retained (M = 568, SD = 72, n = 130) and those that were not (M = 574, SD = 97, n = 12).

Design self-efficacy for all four EDSE factors from sophomore data is provided in Fig. 1. Students that were not retained reported significantly higher anxiety than students that were, t = 2.445 (df = 121, $p < 0.05$). There were no significant differences in the other EDSE measures: confidence, motivation, or expectation of success.

Analysis was done between retention and makerspace involvement to see if there was any connection between this co-curricular activity and staying engaged in the engineering program. There was one notable significant relationship with retention. Students who were retained had experience with significantly more types of making equipment than those who were not, t = –2.207 (df = 120, $p < 0.05$); provided as Fig. 2. In the first two years of their education, students who finished their engineering degrees had used an average of 4.7 types of maker equipment, while students who were not retained only had experience with 3.7. When comparing elective makers and prescribed makers, there was no difference found between rate of retention using a chi-square test of independence, $\chi^2 = 0.065$ ($p = 0.79$).

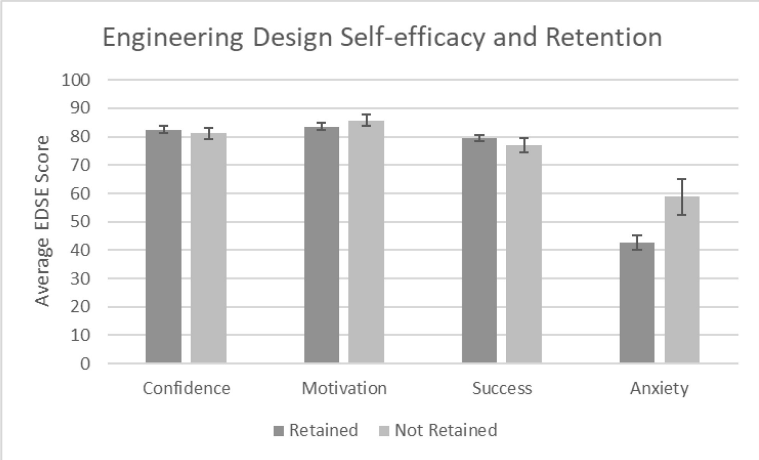

Fig. 1. Sophomore EDSE Scores Compared across Retention.

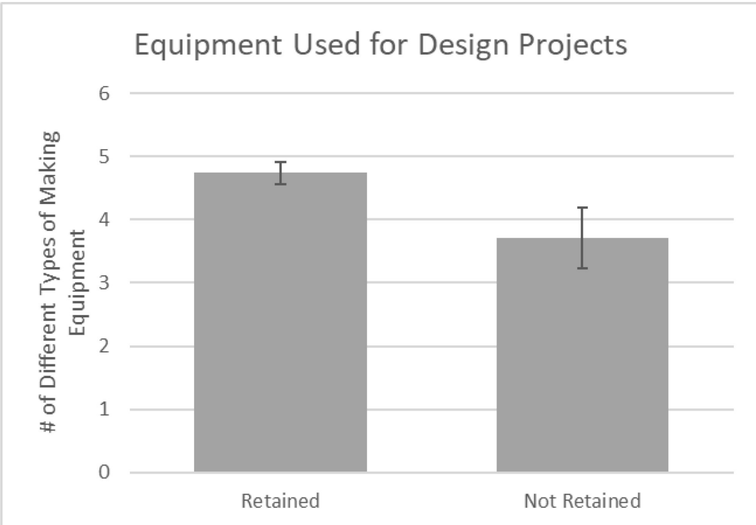

Fig. 2. Amount of Equipment Used by Sophomores Retained and Not Retained.

With respect to the demographic factors, there were no significant differences in retention rate based on gender ($\chi^2 = 0.237$, $p = 0.601$, $n = 169$), under-represented minorities ($\chi^2 = 0.374$, $p = 0.541$, $n = 170$), or first-generation college students ($\chi^2 = 0.005$, $p = 0.943$, $n = 135$).

4.2 Grade Point Average

GPA data was analyzed for sophomore, junior, and senior participants. Relationships were examined between GPA, makerspace involvement, and design self-efficacy. Very few relationships were found between GPA and EDSE measures. Among juniors, there was an unexpectedly negative correlation with motivation in engineering design and GPA, r = –0.203 ($p < 0.05$); students with higher GPAs had lower motivation regarding design projects. All other correlations between GPA and EDSE measures among sophomores, juniors, and seniors were not significant. There were no significant differences in GPA between elective and prescribed makers among sophomores (t = –0.374, df = 83, p = 0.710), juniors (t = 0.811, df = 83, p = 0.420), or seniors (t = 0.557, df = 54, p = 0.580); this comparison is provided as Fig. 3. No other significant makerspace involvement relationships were found with GPA.

4.3 Makerspace Involvement and EDSE Relationships

The relationship between making and design self-efficacy was analyzed among each of the academic years. Among sophomores, two significant trends were identified among EDSE measures: elective makers showed significantly higher confidence than prescribed makers, t = –2.769 ($p < 0.01$), and there was a negative correlation between the amount of making equipment used and anxiety,

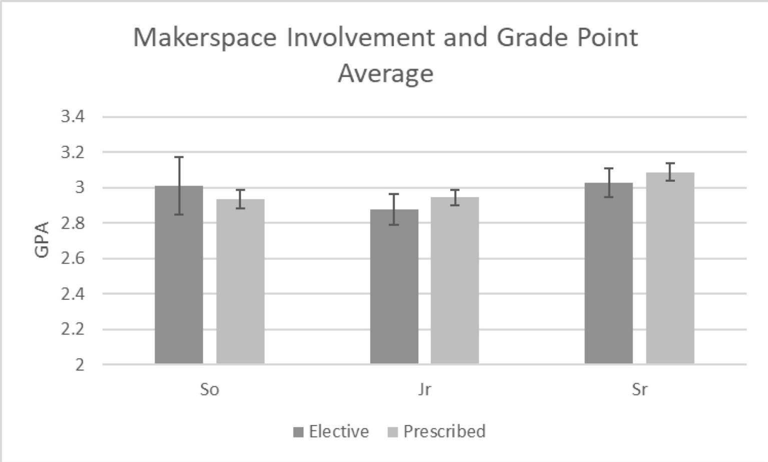

Fig. 3. Comparison of GPA between Elective and Prescribed Makers.

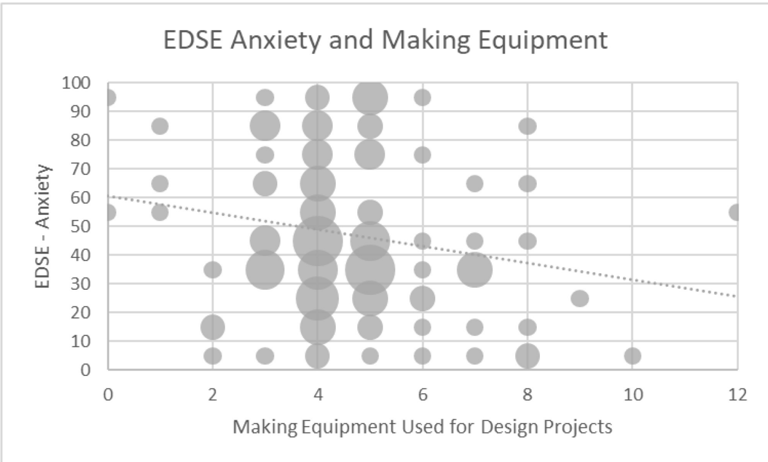

Fig. 4. Correlation between EDSE Anxiety and Use of Making Equipment Among Sophomores.

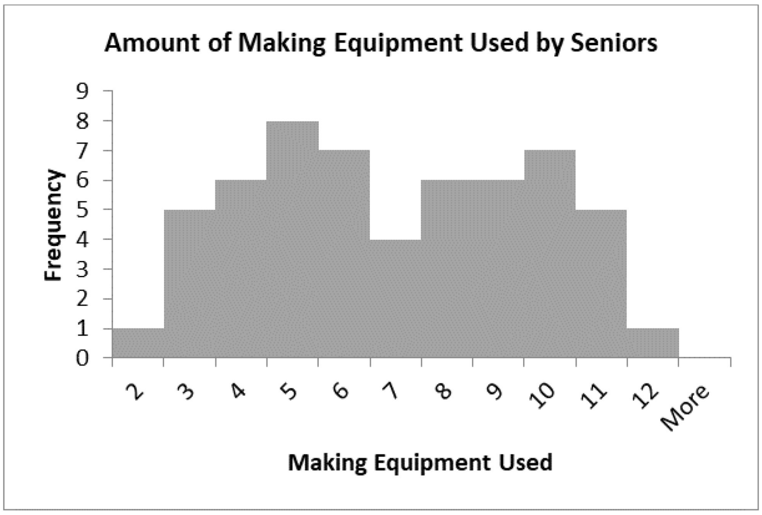

Fig. 5. Frequency Distribution of Number of Different Pieces of Maker Equipment Used by Seniors.

$r = -0.216$ ($p < 0.05$); this correlation is provided as Fig. 4. With regard to juniors, there were no significant relationships found between makerspace involvement and EDSE. Among seniors, a bimodal distribution was identified in the amount of different equipment used for design projects; the frequency distribution is provided as Fig. 5. When comparing students who used more than 7 types of making equipment and students who used 7 or less, students who used more equipment reported higher confidence ($t = 1.749$, $p < 0.10$), higher motivation ($t = 2.116$, $p < 0.05$), and lower anxiety ($t = 1.828$, $p < 0.10$) towards engineering design activities.

5. Discussion

These data shed light on several notable impacts on student retention in engineering programs. It is expected that measures of academic performance correlate with retention. Both GPA and SAT math scores were significant predictors of students who withdrew from the program. It is interesting to note that the effect size between SAT math scores and retention is small to medium (Cohen's $d = 0.33$) given that some call into question the emphasis on standardized test scores in college admissions processes and current university systems' decisions concerning standardized tests (e.g., the University of California System recently reviewed its use of standardized tests in its admissions process [38, 39]). Our sample for this study, however, was limited only to those students who elected to participate in the survey, so the relationship shown may not be indicative of the entire population.

Looking at retention and EDSE, an interesting relationship was identified among sophomores. Students who were retained showed lower anxiety about engineering design than those that were not. This finding has an interesting curricular mapping for this engineering program as students who completed the EDSE instrument during the sophomore year were at the mid-point of their two-course sophomore design experience – a year-long client-centered, community-focused engineering design project. That anxiety tends to be related to retention may indicate that non-academic interventions (e.g., near-peer mentorship programs) may help with student retention. Interestingly, this correlation was not significant for the other EDSE measures.

The main focus of this study is on the relationships between the involvement in the co-curricular activity of makerspaces and academic success. When looking at retention, students who were retained were more heavily involved in making activities. This finding is important for the development of makerspaces on university campuses. While this relationship is only correlational and not causal, it shows that makerspaces are a place where successful engineering students can and do engage in learning opportunities that are relevant to their academic pursuit. This shows that makerspaces could have the potential to improve student outcomes, but more research is needed to show causal effects.

At this institution, GPA was largely independent of other measures in this study. With regards to making activities, there was no significant relationship between GPA and makerspace involvement in any of the academic years. This was consistent with the Hilton et al. [5] study of GPA where no difference was noted in overall GPA between makers and non-makers. For in-major GPA, no significant difference was noted between elective and prescribed makers; there was, however, a difference between makers and non-makers [5]. At the university in the current study, though, we were not able to measure in-major GPA, so the comparison is limited. We note that there is independence of overall GPA and making activity at multiple institutions. In a different study of co-curricular involvement and GPA, researchers have shown that at some point an over involvement in co-curricular activities is connected with lower grades on average [40]. Students putting too many hours towards non-academic activities can distract from their core coursework. Perhaps in this case because makerspaces are applicable to and coupled with engineering coursework, even students who are spending a great deal of time in the spaces are still mostly there for course related activities, and consequently, their engagement is enhancing their curricular learning. In the future, researchers should more directly measure how much time students are spending in makerspaces on course related and non-course related projects and how much time they are spending on other cocurricular activities. This would allow us to clearly differentiate students who were more heavily involved and the relationship to their academic success.

Further, there were no consistent relationships between GPA and EDSE across the three academic years. Among only the juniors, there was one significant negative correlation between motivation and GPA. Perhaps students with high motivation to engage in design activities tend to become involved in time-intensive extra-curricular making that also tends to lower their GPA? There is one curricular possibility at this university: acceptance into the engineering apprentice program occurs at the start of student's junior year. The apprentice program gives students access to paid university-wide machining work, direct supervision, and one-on-one training by a machinist, and given enough work hours (100+ hours on both the mill and lathe), swipe access to the machine shop for afterhours work. So, this trend seems like the trend described above – a moderate amount of involvement in co-curricular activities has a positive relationship to grades while over-involvement is detrimental. This merits further investigation again specifically looking at curricular opportunities.

Previous work found no differences in EDSE scores between voluntary makers and class-only makers at this institution [4]. The previous study was a cross-sectional study that did not separate analyses by academic year, and the data for that study was from a single year of data collection. With the expanded data in this study from multiple years and analyzing within academic year, new relationships between making and EDSE are found and presented herein. Among sophomores, the significant negative correlation between anxiety and makerspace equipment use shows anxiety is the largest predictor of makerspace involvement among the EDSE measures. This is a key finding for getting students involved in makerspaces earlier. If educators can find ways to help reduce anxiety towards engineering design at the beginning of degree programs, more students may be able to get involved and reap the benefits of making. Secondly, we uncovered an interesting bimodal distribution in experience with making equipment among seniors. Across this divide, seniors with more experience with making showed higher confidence, higher motivation, and lower anxiety. We believe this split between seniors could be a form of specialization that occurs within the degree – some students become "makers" likely doing more of the hands-on work for design projects. These "makers" walk away with greater engineering design self-efficacy. That this difference only presents in seniors who are familiar with most of the tools in a makerspace is indicative that there is further growth in design self-efficacy for those that get more deeply involved in making activities.

These data demonstrate, similar to previous work, that students who are more heavily involved in makerspaces have a higher degree of design self-efficacy. This is true even in an environment that has more prescribed making and design activities, which was not found in previous work. This continues to emphasize the value of these spaces as learning environments for engineering design.

Lastly, there is an interesting interaction that has shown up throughout this discussion: Among sophomores, there seems to be an interconnected relationship between three variables: anxiety toward engineering design, makerspace involvement, and retention. Lower EDSE anxiety was associated with a higher likelihood of finishing an engineering degree, a higher likelihood of extracurricular making involvement, and experience using a larger number of design tools. And similarly, a higher degree of involvement in makerspaces was connected with a higher likelihood of finishing an engineering degree. This suggests that addressing students' anxiety around engineering tasks is critical for better outcomes and engagement. Researchers should continue to look for ways to decrease anxiety about engineering design, and as parallel relationships were not identified with the other measures of EDSE, possibly, anxiety around engineering design is a larger obstacle to overcome than other aspects of design self-efficacy.

6. Limitations

The context of this study proved to be a limitation as well as a strength. The university engineering program being so design and making centric makes this a unique and appealing context to study makerspace involvement. The uniqueness, however, may limit the degree to which these results can be extrapolated to other universities. Future studies should examine these same phenomena within other engineering programs. This would provide a better understanding of the academic impacts of makerspaces as well as context to interpret the results in this study. For the retention analysis, the overall retention rate observed for sophomores was 85%. This is a high retention rate for this engineering degree program. Participation in the survey study was voluntary. Therefore, choosing to participate in this study may have self-selected a group of students who were more likely to retain than typical, which could possibly skew the results from the retention study. Lastly, as with any longitudinal study there is a limitation of the completeness of data. Because this study took place over a large period of time surveying many students, many participants had missing data in some aspect of the study or another. These holes in the data limit our results and significance.

7. Conclusion

This study examines relationships between makerspace involvement, academic performance, and engineering design self-efficacy at a university that incorporates making and design into their engineering curriculum. Makerspaces are playing a larger role at universities across the country, and it is important that we understand their relationship to other student outcomes. We found that being involved earlier in making related to a higher likelihood of finishing an engineering degree, but further investigation would be needed to determine causation. On the whole, makerspace involvement was independent of GPA, which reinforces that makerspaces can have a positive impact without detracting from student education. Lastly, we found that lower anxiety was most strongly related to positive outcomes with making and academic performance. Educators and researchers should work to find interventions to reduce this anxiety towards engineering design for students to enable them to engage more fully in engineering programs.

Future analysis will compare and contrast these data with another university with a more traditional mechanical engineering curriculum to explore the differences making has on students' academic journey.

Acknowledgements – This work is supported by the National Science Foundation through Award Numbers 1432107, 1733708, 1733678, and 1431923. Any opinions, findings, and conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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