Knowledge in the Making: What Engineering Students are Learning in Makerspaces

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Knowledge in the Making: What Engineering Students are Learning in Makerspaces

Introduction

Extensive funding and resources have been allocated to support the integration of makerspaces in undergraduate engineering programs and, with greater investment, there is growing likelihood that engineering students are expected to use the spaces as part of their coursework. The investment in and placement of the spaces within colleges of engineering, specifically, provide warrant for anticipating that engineering faculty members are assigning projects that require students to engage in the space to complete the assignments.

Makerspaces are usually well equipped with rapid prototyping equipment, hand tools, computers, and other equipment that could be used to make or create products or prototypes. Makerspaces have gained popularity [1] and continue to be popular with the expectation that students interacting in the spaces will learn a range of skills and content [2]-[5]. Promotion of makerspaces is based on the expectation that when students access and engage in making activities, they are also engaging in some of the practices and norms of engineers. The spaces provide a unique context for research and the exploration of what students may be learning in professionally-geared learning environments. For example, some of the research on learning in makerspaces has focused on student achievement of engineering program goals for learning outcomes when they use of the spaces as part of their engineering preparation programs [6]-[8]. Other university-based makerspace research projects have focused more on students' preferences for the spaces [9] or other space-related constructs such as creativity [10].

Yet little is still known regarding… Our research concerns the perceptions, experiences, and learning by the engineering students and faculty members working within university-based spaces associated with formal engineering programming. For this case study research, we conducted a combination of observations and interviews of students and faculty members working in engineering program-embedded makerspaces. This paper focuses on one of our six university cases - a makerspace embedded into an engineering education program at a large research university. The focus of our research was on student learning and faculty members teaching a combination of engineering content and process knowledge in particular those associated with a 21st century engineering mindset. More specifically, we were seeking to determine the influence of working in the space on students' sense of belonging, professional identity development, and on their motivation for learning which included growth mindset and learning goal orientation.

Review of Literature

21st Century Engineering Knowledge and Practices

There is a growing body of research reporting the influence of makerspace work on student learning of engineering concepts and processes [4], [6], [11]-[13]. Makerspaces potentially provide a setting for fostering student development of critical engineering concepts and processes ranging from leadership characteristics [15] to understanding and application of the design cycle [4]. However, few studies have explicitly examined student learning through the lens of the knowledge and practice expectations of a 21st century engineer [14]. Yet, 21st century skills have been embraced by the Accreditation Board for Engineering and Technology (ABET) and are included in the standards for engineering programs [15]. The 21st century skills include collaboration and teamwork, creativity, communication, emotional competency, cultural competency, ethics, leadership and management, critical thinking, and content knowledge. A fundamental shift in the ABET engineer paradigm with the adoption of the 21st century framework reflects a focus on engineers as being at the service to society. The ABET standards suggest that there is justification for exploring the extent to which engineering student engagement in makerspaces is fostering and promoting their development of a 21st century engineering mindset and their acquisition of 21st century engineering knowledge.

Sense of Belonging

In makerspaces, students are likely to work closely with others or in teams on [16-21]. The social and cultural interactions that take place in the spaces likely influence the students learning [22] but also their sense of belonging. Yet, there is a need to empirically investigate the extent to which student interactions in the spaces influences their learning and how the culture within the spaces may lead to student feelings of inclusion or exclusion. The social interactions and the culture of the spaces may be key to documenting the influence on student learning, providing justification for documenting the levels of comfort in these spaces, feeling of belonging in the spaces, and the nature of student social interactions within the spaces.

As we shared before, a student's feeling of belonging in a learning environment is likely to impact their learning. Maslow's Hierarchy of Needs [23] states that human beings are motivated to feel a sense of belonging. It is possible that the learning that students gain from activities in makerspaces, is associated with their sense of belonging or a sense of being valued by others in the space. Thus, there is justification for determining what is taking place in the spaces to make people feel welcome in the spaces, and how the culture is being fostered to help students feel they belong in the spaces [23].

Professional Identity Development

The level to which individuals identify with a profession is influenced substantially by the level to which individuals hold schemas, engage in practices, and follow the norms of the profession [25]-[26]. If students perceive that they do not look, sound, act, and use tools like other engineering students, they may not identify with others doing engineering activities and, therefore, fail to develop and internalize an identity for the profession [27]. The opposite is true as well, if students can identify with the culture, the tool use, engineering tasks, and people associated with engineering activities they are most likely to develop and internalize an identity for the profession. We conjecture that engineering students' development of an identity in the engineering profession is influenced substantially is aligned with the culture or setting where they are learning about engineering. We speculate that in the setting of makerspaces students may form perceptions of their professional ability, a sense of belonging, and capacity to understand and carry out engineering activities.

Given the high potential for an association between professional identity development and engagement in makerspaces, we maintain there is justification for examining the extent to which makerspaces might be designed and supported to foster students' professional identity development. The culture of most makerspaces may require the individuals in the space to assume a large level of responsibility for their learning and success in the spaces [27]. Assuming or owning the responsibility for success in a makerspace may require students to embrace and understand the norms, activities, and practices in the space - which we maintain are indicators of developing or growing a professional identity [25]-[26]. Understanding more about how makerspaces are, or are not, supporting students' professional identity development in a makerspace will allow us to determine whether these spaces are enhancing or hindering students learning and development as professional engineers.

Motivation for Learning

When considering motivation for learning, and work towards learning, we consider Dweck's concept of growth mindset [28], which highlights the importance of individuals' need to learn persevere through situations with unexpected outcomes they may encounter [28]. Alternatively, a learner who approaches situations with a fixed mindset would be unlikely to persevere when they experience failure and therefore would likely disengage from the additional efforts necessary to complete the task. We speculate that makerspace activities may foster a growth mindset as associated activities may encourage students to perceive trial and error, and failure, as instrumental to the learning and professional development process. Encouragement of repeated attempts and perception of failure in may, additionally, lead students to explore additional solutions with less fear.

We consider persistence as an indicator of motivation for learning as persistence is represented by sustained engagement and effort toward mastering understanding and completing assigned tasks particularly when encountering or perceiving challenges, barriers, failure, and/or adversity [29]. We considered the elements of motivation and persistence within the context of students learning engineering or engaging in engineering-based makerspace activities. Exploring persistence as it relates to the influence of makerspaces on undergraduate engineering students provides us with a framework for delving into how and why makerspace engagement may influence students' propensity to remain engaged in studying engineering despite facing academic challenges and barriers.

We also consider motivation through the framework of self-determination theory (SDT) [30]. We take into account SDT due to the intrinsic and extrinsic motives related to learning. Motivation for learning is critical in the makerspace environment where students are usually provided with an assignment to complete (an external motivator) that requires them to engage in the makerspace to complete (likely to involve some intrinsic motivation). We seek to document where motivation lies for students to engage in makerspace activities, on the extrinsic-intrinsic spectrum.

Method

Research Questions

Our overarching question for our research was: To what extent do engineering education programs that embed makerspaces foster student professional development, sense of inclusion, motivation to learn, and support professional identity development? To answer our primary research question, we developed the following guiding research questions:

1. To what extent do students working in the makerspaces convey a sense of belonging and increased motivation to learn and in what ways do faculty members, staff, and the director convey an expectation for students feeling a sense of belonging and increased motivation to learn when working within a makerspace?

2. To what extent do students working in the makerspaces convey perceptions reflective of professional identity development, and learning more about engineering, and in what ways do faculty members, staff, and the director convey an expectation for students to experience increases in their professional identity development and knowledge of engineering when working within a makerspace?

3. What do faculty members and students perceive to be necessary for students to be successful within a makerspace?

Participants and Setting

The participants in our study were the students, staff, and faculty members interacting with or working within an engineering program embedded makerspace during two days of data collection. The setting was a large, public, and high research activity university in the southern region of the United States with large undergraduate and graduate engineering education programs. We limited our demographic data collection across three roles at the university (student, faculty member, or staff), which we report out alongside and gender. To maintain the participants' anonymity, we did not gather additional detailed personal information. We interviewed four faculty members, five staff members, the director, and more than 20 students.

To preserve the anonymity of the participants and institution, we also describe the space in general terms. The makerspace of our focus was large and centrally located within a cluster of buildings used for STEM research, teaching, and faculty offices. The space was free to use (including many materials) and open to all students taking engineering classes. The space was accessible daily and open at selected times on the weekend. There are other spaces on the campus that non-engineering students could use for making and working on projects. The space had staff and a director and included an array of machines and tools that could be used for prototyping. Students were encouraged to work on personal projects and were provided some of the needed materials free of charge if the projects were small. If the projects were large, the student was expected to purchase the supplies. Students had access to almost all of the equipment after being taught how to use the equipment by the space staff and then demonstrating competency in the use of the tools.

Student use of the space was integrated to some level in approximately 30 courses (i.e. students were given assignments that required them to use a makerspace to complete), from introductory courses that open to non-engineering students to capstone design courses for senior engineering majors. The number of courses for which the space was utilized by students was expected to increase in the next academic year.

Data Collection

We have designed our project using both instrumental and collective case study frameworks [31]. We are currently in our instrumental case study phase, detailing the particulars of each university program. Following the completion of our instrumental work we will engage in a collective case study framework to determine similarities and differences across programs to form a comprehensive perspective of makerspaces embedded within engineering education programs.

The cases for our research are university undergraduate engineering education programs that have College of Engineering integrated makerspaces. To collect data from these spaces we are using a combination of surveys, observations, and interviews. The focus of our report is on the interview data that we gathered from a single case.

We gathered the data through interviews of students using the space, faculty members integrating the student use of the space into their curriculum, and staff and director managing the space. We arranged some faculty member, staff and director interviews prior to visiting the university. We were able to make additional interview appointments with faculty members once we were on the campus. The interviews lasted about 20 to 30 minutes.

To interview the students, we approached students working in the makerspace and asked them if they had time to share some of their thoughts about working the space. Some of the student interviews were relatively brief, about 5 to 10 minutes, others lasted longer, 20-30 minutes. The interviews varied based on the students' interest in talking to us, the time they had available to talk to us, and their level of comfort in talking with us.

We recorded the interviews and transcribed them verbatim for analysis.

Interview Protocol

We developed two semi-structured interview protocols, one for students working in makerspaces, and another for faculty members, staff, or space directors working within the spaces. In our development of the student interview protocols we created a series of discussion prompts to focus student conversation on their perceptions, interactions, and work within the space. We aligned the prompts to our major constructs of motivation, professional identity, belonging, and learning of engineering. We contextualized the prompts to make them relative to the interactions students might experience in makerspaces. For example, one prompt asks, "What's the value of being in a makerspace?" which could allow for exploration of constructs of persistence, professional identity development, competency, motivation and belonging via students' references, for example, to learning more about the processes of engineering (such as collaborating on a project), increased motivation to work on their projects (even when the projects were difficult to complete), or a sense of being part of a community in the space. Our student interview protocol included ten prompts. We validated the interview protocol by sharing with a group of six experts in makerspace development and use.

We took an approach similar to the development of the student protocol to create the faculty member, director, and staff interview protocol. Again, we developed a series of prompts aligned with our major constructs. However, we contextualized the questions to focus the conversation on ideas such as expectations for students using the space, integration of the space into the curriculum, and assessing the success for student use in the space. For example, one prompt asks, "Are there other things you are hoping students gain from their participation in makerspaces?" Similar to the student protocol prompt we shared, we anticipated that the faculty member, staff, and director prompt would solicit responses that would include references to all of our major study constructs. The protocol includes sixteen prompts. Again, we validated the interview protocol by sharing with a group of six experts in makerspace development and use.

Data Analysis - Coding

To analyze our data, we used a combination of a-priori and emergent codes. We developed our a priori codes for the major constructs of our study based on relevant literature and contextualization for our research. For example, a priori codes concerning sense of belonging are partially based on the work of Maslow [23] and the essential need to belong which includes friendship, trust, acceptances and being part of a group. Contextualizing belongingness for student engagement in makerspaces codes results in codes for feeling comfortable in the space and feelings of inclusion in the space (see Table 1). The codes are indicators of the attributes associated with each of the constructs. We achieved intercoder agreement by independently coding one transcribed interview and then compared our outcomes. Our results overlapped at nearly 90%, which indicates acceptable coding reliability. Once we established the agreement we divided the transcripts for coding. We also remained opened to the possibility that our participants may share unanticipated perceptions or experiences and, therefore, we remained open to emergent coding. When we found other area themes emerging that we did not anticipate we communicated the finding and worked together to develop an appropriate set of codes. See Table 1 for the construct-aligned codes we used to analyze our data.

Results

Table 1: Study Constructs, Associated Codes, and Examples of Representative Responses

Construct	Codes	Example Representative Responses

Sense of Belonging	Holding a role within the space, sense of purpose, emotions, availability of knowledge, accessible and visible, intimidation, student perceptions, inclusion, breaking barriers, students feeling comfortable within the space, tailoring environment to students	**Student:** "belong? just like have a sense of like responsibility here?" **Student:** "I think it's more inviting just because it's so central in this building." **Director:** "We didn't want to have any kind of barriers whatsoever. So we picked those color tones to make it really inviting for everybody."
Motivation	Desire to work/learn, use of equipment for coursework, use of equipment for personal projects, ease in learning, application of skills, enthusiasm, engagement, self-efficacy, struggle, creative expression	**Student**: "It's like we don't want to spend more time here than we have to. I mean not in a bad way like I love this space." **Student:** "So I'd really like to come in and make something I've just been busy you know." **Director:** "It's people that I see here on a daily basis coming in utilizing the equipment, having that spark, that desire to be here."
Affordances and Challenges	Student independence, individualized learning, process of learning, safety, autonomy, forced adaptations, constrained time for faculty and students, challenges, sustainability, resource availability, use of resources, space limitations, expenses associated with makerspace	**Student**: "… and then timing management is, well like we said another big lesson." **Faculty**: "Well I think probably the biggest skill, I don't know if it's a skill, life skill is not procrastinating." **Staff**: "When using a CNC machine for the first time you're probably going hurt somebody if you mess something up" **Faculty Member**: "There's only room for about 6 or 7 projects in the semester. So which ever one you choose to focus on, that's going to eliminate another one."
Curriculum Integration of Makerspace	Coursework, skill building, use of the space, projects, training, group activities, application of knowledge learned, faculty involvement, learning opportunities	**Faculty Member:** "I think as people hear about it they'll start to think" oh maybe instead of a homework assignment they can make something." **Student:** "We only have so many hours in class where you're just learning theory right? In here you're actually applying stuff." **Student**: "…because these 3D printers are actually shifting the way that class is designed. We now take things a step further and produce an actual, physical deliverable."
Learning Engineering and Professional Identity Development	Working with a client, resume/skill building, engineering skills, trial and failure, practical applications, real world use of skills, career goals of students, collaboration, prototyping, decision making, gaining experience	**Student**: "Whereas now I have that experience. Now I can add more things to my resume." **Faculty Member:** "I think we really just strengthen those hardcore engineering criteria." **Staff**: "You learn through failure. Mess up! Mess up because you're going to learn the most from messing up."

Results

Belonging and Motivation

Our first guiding research question asked, In what ways do Do students working in the makerspaces convey a sense of belonging and increased motivation to learn and do in what ways do faculty members, staff, and the director convey an expectation for students feeling a sense of belonging and increased motivation to learn when working within a makerspace? To answer this research question we coded our transcripts for perceptions of belonging and motivation to learn.

We found multiple instances in which students indicated that they felt welcome in the space such as what this student shared, “I definitely believe that we belong here as engineers because this was given to us for that purpose.” The director of the space works to assure students feel included as is apparent by this response, “I want to break down that those little barriers, whatever they are and just make them feel comfortable and welcome and tell them that hey, you don't have to know what's going on and there's training here for you and you don't have to be intimidated.” Thus, students indicated coming into the space knowing how to use the equipment, and the director worked to create an environment of inclusion.

In a conversation with three self-identified female students who were in the space for their second time, they shared that they were reluctant to visit the space their first time because they did not know what to expect. They shared that they had a successful experience and felt welcomed and valued and therefore, had no hesitation returning to the makerspace to continue working on their project. The conversation reflects a sense of comfort and inclusion in the space for these students. We encountered a similar response from two other female students who were working on homework in the space and enjoyed being in the space because it was stimulating and they felt comfortable working in the space.

To determine if students were motivated by the space, we coded the interview transcripts for indicators of engagement, interest, and initiative. We found that many students enjoyed exploring in the space beyond working on their assignments, but when working on course assignments, the students were really engaged. We had multiple conversations with groups of students working together on courses assignments. (Note: several of these conversations were unanticipated and therefore, were not recorded.) It was in these conversations that we found the students indicating that they were excited about working on the assignments, as when students indicated that they were spending more time on the projects than they typically did on more traditional assignments due to developing solutions they could create by using the tools in the makerspace. In our conversation with a faculty member who held office hours in the space, he shared, “It's people that I see here on a daily basis coming in utilizing the equipment, having that spark, that desire to be here.” This supports our earlier conclusion that students using the space are motivated to be there and are engaged when they are in the space. Many of the responses of the students reflect a similar level of motivation to be in the space and engage in learning activities. For example, one student shared, “It's free to students. You only have this opportunity while you're here. I really like to come in and make something.” Thus, the students are motivated to visit the space and use the space for working on projects.

Professional Identity Development and Learning Engineering

Our second guiding research question asked: In what ways do students working in the makerspaces convey perceptions reflective of professional identity development, and learning more about engineering, and in what ways do faculty members, staff, and the director convey an expectation for students to experience increases in their professional identity development and knowledge of engineering when working within a makerspace?

To answer this research question, we coded our transcripts for perceptions of belonging and motivation to learn. Our analysis revealed that faculty members perceived that students are gaining valuable skills in the space as is indicated by this response, "Students learn the skills which are beneficial to a student's professional development: adding skills to resumes, presentations of projects, and creating a product for a client." The creation of client products and presentations are fundamental engineering processes and require professional skills and knowledge which seems to be reinforced by work within the space. Another faculty member shared a similar perspective in the response, "I think we really just strengthen those hardcore engineering criteria."

The students also indicated that they were learning more about engineering in the space as indicated by this response, "We've already had to make some solutions-modifications. I think that applies to life as well as engineering, because you know, it's never going to go 100 percent to plan." Similarly, a student responded with, "It's nice to feel that push from professors to incorporate the use of the space in their classes, to let us know that it's okay to experiment and it is okay to do it once and okay if it doesn't come out how you wanted it to."

In the space the students were almost always working in teams, particularly on assigned projects. The communication, collaboration, and interactions are aligned with the norms and practices of professional engineers. Thus, the space reinforces student development of a professional identity. The autonomy and support for the students in the space further provides them with the opportunity to internalize the opportunity to gain the skills and knowledge of a professional, leading to opportunities for professional identity development. Also, the nature of the assignments in the space reinforce the potential for professional identity development, as this faculty member shared, "It's good for them to be ambitious, but if they're ambitious and fall short, which they probably will, there's value in that." Given that dealing with failure and persisting via it are fundamental to a professional engineering mindset, makerspaces may provide opportunities to further develop an identity as a professional.

Other Space Considerations For Student Success

Our third guiding research question asked: What do faculty members and students perceive to be necessary for students to be successful within a makerspace? To answer this question we analyzed our data focusing on the barriers and affordances associated with working in the space. We exposed two major themes: time and safety. Time was conveyed as a barrier by both faculty members and students, as both expressed the need to exercise additional time management skills within the space. As one student shared, "And then time management is, well, like we said another big lesson." Similarly, a faculty member expressed that students often share that they learn time management skills in the space. Yet, some faculty members realize that they need more time to effectively use the space in their courses. As one faculty member shared, "I find it embarrassing that I do not know how to do this stuff. I wanted to go do the 3D printing assignment but there's just like..." (Interviewer) "Time?" (Faculty)" I have to do proposals." Thus, while faculty members want to use the space they have competing responsibilities that may take precedence, which limits the ability to develop meaningful and appropriate assignments. As this faculty member shared, “So they could end up easily spending 20 or 30 hours at it and it’s just not worth it.” indicating that makerspace assignments could be structured in ways that take significant time with learning outcomes that are less than expected given the time invested.

Another major consideration that was shared multiple times by staff and the director were issues of safety. As the director shared, “You've got to look at the safety aspects. You invite environmental health and safety in to determine the requirements here at the university to actually introduce new equipment.” Thus, while efforts are in place to create a space with a range of capacity to foster innovation, there are certain challenges with safety that may limit opportunities because of cost or physical feasibility.

Discussion and Implications

The primary goal of our research was to determine what faculty and students perceive are afforded students through their experiences in engineering education program embedded makerspaces. In particular, we were interested in determining what the students were learning about engineering, to what extent the experiences helped the students develop their identity as professionals, and how working in the space may motivate students to learn and feel like they are included in the engineering community.

Given the limitations of this study, we speculate that the activities and expectations of working within makerspaces may foster student motivation to learn. One of the primary functions of the engineering education program makerspace is to support rapid prototyping. Part of the prototyping process is working on open-end problems with multiple potential solutions. Because there is no one correct answer the students have much more latitude to explore and develop different solutions. We posit it is the open-ended nature of the problems that lead students to be motivated to work in the spaces. Further, the ability to develop rapid prototypes in the space makes the cost of change lower and encourages students to continue to explore new possibilities.

We found evidence of students expressing a sense of belonging in the space. We attribute their sense of belonging to the community that has been established within the space through the removal of barriers and creating a non-intimidating environment. We found a concerted effort to make the space inviting and pleasant to work within. The creation and support for students as a community of learners in the space, and providing the resources and training to use the tools and equipment led the students to have positive experiences in the space. Leadership may be important to creating an inclusive environment, as per director claims.

We found that students gained deeper understanding of engineering via working within the space. We posit that the processes of the activities that the students work on in the space and the availability of the tools to experiment with different solutions leads students to understand the importance of failure, collaboration, critical thinking, optimization, and constraints. The students also indicated that they were able to apply their knowledge in the space toward the development of a product, a process that was not taking place in their more traditional coursework. The faculty members’ recognition of the learning benefits from working in the space may lead to additional curriculum integration and more opportunities for student learning through the application of knowledge which may help them further develop as engineers.

We found that the spaces supported students' development of professional identities. We speculate that the autonomy that students have in the space, the nature of their assignments in the space, and the culture within the space all foster student development of perceptions of being part of a professional community. Further, we conjecture that the support the students have in the space to explore requires the students to take responsibility for the time in the space (i.e. time management) which is a very important professional skill. Because the spaces are more student centered and less structured than more traditional learning environment, the spaces are ideal for supporting activities that are aligned with professional engineering, which further fosters student internalization of themselves as professionals. By integrating makerspace activities into the curriculum, faculty members can help catalyze student development as professional, positively impacting their development of an identity that includes being a professional.

Our analysis revealed that time and safety were aspects of makerspace use that we did not anticipate to be so prevalent. The issue of time is a noteworthy consideration when structuring lessons for students. Because of the open-ended nature of many of the projects in the space, students could spend considerable amounts of time in the space working on the projects and exploring multiple potential solutions. Thus, faculty members may need to prepare their students to consider their time (and associated management of their time) within the space so that work in the space is not at the expense of other commitments or responsibilities. Thus, when assigning makerspace assignments, faculty members may want to have the students monitor their time on the projects and collect the data from the students and use the information to refine the assignments to optimize learning.

The attention to safety in the spaces is essential, particularly with large milling machines, cutters, and other power tools. The potential for harm in the spaces due to lack of knowledge or careless use was being addressed through training and monitoring. Again, the leadership in the space took a progressive approach to not access but rather prepare people to use the equipment properly through educating them. We maintain that through attention to safety, students can be more engaged and productive in the spaces, and can also gain a deeper understanding of safety in the workplace, which influences their engineering knowledge and professional identity.

Limitations

Our first limitation is that our data is from a single case of a university engineering education program embedded makerspace. Therefore, the perceptions, experiences, and expectations for makerspaces in engineering education may be very different at other institutions. However, through our case study analysis we were able to gain beginning understanding of the experiences of students in the spaces, faculty member uses and expectations for the space, and the influence of the use of the space on an array of constructs. We are gathering data from other cases and continue to explore how the spaces are similar or different for student learning and development.

The second limitation of our research was the limited number of students and faculty members we were able to interview. We did talk with over 20 students and 4 faculty members, but given there are thousands of students and hundreds of faculty members, the perceptions and expectations and experiences of our participants may not have been representative of the larger college community. Gathering data from additional participants will allow us to develop a more accurate representation of the greater university engineering education community.

A third limitation of our research was our focus on the students who used the space, and did not seek data from those students who avoided being in the space. Gathering data from those who chose to be in space may have resulted in telling only half the story, reflecting the perspectives of only those who felt comfortable and included in the space. We would have liked to gather data from those students who perceived that they were not welcome in the space or avoided the space for other reasons, but we had no way of readily locating these students. As we move forward with our research gathering data from students who were avoiding using the space would be a very interesting direction for our research.

Conclusion

We are seeking to better understand what students are learning and experiencing in makerspaces embedded into university engineering education programs. Thus, we are conducting a case study research project of makerspaces embedded in undergraduate engineering education programs. We are considering an array of variables that are associated with student knowledge, retention, engagement, and professional development. The evidence that we gathered at the case we detailed in this report indicates positive support for student learning and development as engineers. The structure, management, use, culture, and support within the space made the space inviting for students. The students in the space were gaining from their experiences. Our results indicate that if makerspaces are created and supported effectively, the students working in the spaces are more likely to experience positive gains in their journey preparing to be engineers.

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