Integrating Makerspaces into the Curriculum – Faculty Development Efforts

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***Abstract*— This full paper describes three approaches taken by the University of New Haven to support and train faculty to integrate the makerspace into their course content.**

As one way to promote hands-on learning with engineering students, many faculty and staff support the integration of makerspaces into higher education classrooms. Encouraging students to use a makerspace can result in an increase in informal learning opportunities, additional support for prototyping efforts for project-based learning, increased self-efficacy, and an enhanced sense of community and belonging. As makerspaces are relatively new in academic settings, many faculty are unfamiliar with the capabilities of the equipment in these spaces and may be unlikely to adopt usage of the tools into their courses. With many of the maker technologies not used by faculty during their own studies or career development, additional training opportunities are needed to provide faculty an opportunity to develop their own mastery of both the new technology and specific classroom pedagogy related to "making." Faculty training for makerspaces is more than just professional development on new technical content. For a successful integration into the classroom, faculty members should consider relevant pedagogy, time considerations, budget constraints, equipment limitations, and the added-value of the maker element to the traditional classroom content. This study profiles three different types of faculty development makerspace training efforts: self-guided exploration by enrolling faculty as members of a community makerspace, pedagogy-focused workshops, and hands-on equipment training sessions.

The first effort provided 20 faculty members access to MakeHaven, located in downtown New Haven, CT. With this membership came access to training, mentors, workshops, and a supportive community. To engage with the equipment and resources, faculty were encouraged to work on projects of their own interests and for their own purposes. As their projects were individually different, they needed to seek out the assistance of the expert user; in doing so, they learn by doing, by trying it out and revising. A second effort brought in an external speaker to host a mini-workshop for approximately 18 faculty. The speaker introduced the pedagogy for incorporating makerspaces into curriculum efforts and provided practical examples of incorporation across majors. Participants completed a brainstorming and planning exercise to identify a course and maker-project for implementation. The third effort provided 10 faculty and staff the opportunity to participate in workshops specifically targeted to introduce faculty to the University of New Haven makerspace equipment. Faculty and staff learned about the equipment and its manufacturing capabilities, discussed tips for classroom integration, and then designed and created a product of their own using the equipment.

Post-event surveys were completed after each effort to highlight strengths, weaknesses, and future plans. Follow up surveys and interviews were conducted from selected participants of each training type to gather information on the classroom implementation, faculty knowledge gaps, and student successes. These results are analyzed to provide specific recommendations for the most effective methods of makerspace faculty training with the purpose of classroom integration.

Keywords—makerspace, faculty development, case study

I. Introduction

Makerspaces are now considered an important part of engineering education for current higher-education institutions as they provide opportunities for students to be creative, to learn from failure, and build a sense of community. These spaces are collaborative spaces where individuals can work on projects and share resources and ideas. The equipment and resources available at each space tend to vary widely but in general include basic tools for prototyping such as hand-tools, 3D printers, laser cutters, and electronics, while also including craft tools such as sawing, painting, and vinyl cutting resources. Research by Lenhart *et al.* use a Structure-Agency Theoretical framework to explore faculty perceptions of what the makerspace contributes [1]. Their results suggest that faculty believe makerspaces afford students access to tools, equipment, and supervision that may not otherwise be available to them. Other faculty perceptions of the makerspace may include more real-world scenarios that can lead to skill development [1-3], peer communities to learn in and from [1], and a general tendency to innovate courses for more project-based or active learning experiences [1, 4].

If makerspaces are going to be implemented into a curriculum, the faculty and staff need new training. Why do university faculty need training to teach in a makerspace? Vigeant et al found faculty were curious about using the makerspace, but found it challenging to personally learn the equipment and tools before they could comfortably assign them to student projects [5]. Dahal found only 30% of faculty in the college of engineering and the college of arts and science had ever personally used a makerspace, and found that 44% of faculty interviewed were unsure of the available tools in the makerspace [2]. It's no surprise then that Lenhart et al found faculty desired additional professional development in order to understand how to effectively teach in makerspaces [1].

In order to overcome many of these concerns, a small number of formal faculty development opportunities to learn about teaching in makerspaces have been developed. There are only a small number of nationwide opportunities for faculty development in makerspaces. *B-FAB*, or the Bucknell Fabrication workshop, is a 3-day experience for faculty and staff to introduce makerspace equipment, discuss pedagogy, and plan for classroom implementation [5]. KEEN has offered the *Making with Purpose* Faculty development program as a 4-day event that focuses on Entrepreneurial Mindset (EM) faculty development through makerspace projects and pedagogy [6]. Other faculty development efforts tend to be targeted at campus-specific initiatives, such as offering makerspace training and cohorts [7] or offering grant opportunities for faculty interested in integrating the makerspace in their own courses [8].

With such a significant need for faculty development training on makerspaces, how do we ensure that the training translates into adoption by faculty into the classroom? We propose that encouraging faculty to adopt and integrate the makerspace into their courses follow the Model of Diffusion of Innovation theoretical framework by Rogers [9], which explores how individuals might react or adopt to a new idea or innovation. This framework uses a five-stage model including:

1. Knowledge- a first-exposure to the innovation, but often not at the stage of inspiration yet.
2. Persuasion- interest in the innovation, actively seeking out more information to learn.
3. Decision- after understanding costs and benefits, the individual will decide to adopt or reject the innovation.
4. Implementation- the initial deployment and testing, continuing to examine both usefulness and costs/benefits.
5. Confirmation- the individual finalizes their decision to continue to use or reject the innovation.

This framework has been used to explore faculty development initiatives from a perspective of integrating an Entrepreneurial Mindset into engineering capstone courses [10] and general faculty development [11]. In our application, the various training opportunities touch on the first four stages of the model (Knowledge through Implementation), and our survey explores which trainings, if any, may encourage faculty to achieve the Implementation and Confirmation stages.

This paper explores the impact of three different approaches to faculty development related to the makerspace. In specific, this work attempts to explore:

1) Is there a specific method of faculty makerspace training that is more-likely to result in classroom adoption by the faculty member?

2) What are the barriers, even after training, that prevent faculty from integrating the makerspace into their course?

II. Faculty Development Methods

Between Summer 2019 and Spring 2020, two engineering faculty at University of New Haven led three different initiatives to encourage faculty from all academic background and colleges to integrate the makerspace into their academic courses.

The first effort provided up to 20 faculty members access to MakeHaven, a community makerspace not associated with the University. With this membership came access to training, mentors, workshops, and a supportive community. To engage with the equipment and resources, faculty were encouraged to work on projects of their own interests and for their own purposes. As their projects were individually different, they needed to seek out the assistance of the expert user, in doing so, they learn by doing, by trying it out and revising. At the end of their summer program, the faculty were expected to showcase their projects during a MakeHaven Open House.

A second effort brought in an external speaker to host a mini-workshop for approximately 18 faculty. The speaker introduced a structured pedagogy for incorporating makerspaces into curriculum efforts, and provided practical examples of incorporation across majors. Participants completed a brainstorming and planning exercise to identify a course and maker-project for implementation.

The third effort provided faculty and staff the opportunity to participate in specialized 2-hour workshops that introduced a specific piece of equipment in the makerspace. During the workshop, the facilitator discussed the physical equipment, relevant related software, and appropriate pedagogy considerations for implementation into classes, and then helped faculty create a design and use the equipment on their own. Eleven faculty and staff participated in these during the Fall 2019 semester during two different training sessions showcasing the laser cutter. The participants explored general uses of the laser cutter and then made name-plates using the laser cutter on acrylic or balsa wood. While other equipment-focused workshops were scheduled for Spring 2020 semester, they were not able to occur due to the pandemic.

Post-event surveys were completed after each effort to solicit both strengths and weaknesses of the training, as well as the faculty's future plans. Follow up surveys were conducted three months and one year after the conclusion of the trainings from selected participants of each training type to gather information on the classroom implementation, faculty knowledge gaps, and student successes. These results were analyzed to provide specific recommendations for the most effective methods of

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makerspace faculty training with the purpose of classroom integration.

III. Results

In order to determine the success of the various efforts, both immediate post-training evaluation survey data and a follow-up survey were analyzed.

A. *Post-training survey data from MakeHaven faculty access*

Faculty members who participated in the MakeHaven faculty summer program were asked to participate in a survey regarding their experience at the community makerspace.

The online survey consisted of multiple-choice questions, Likert-Scale questions, and open-ended questions. Responses were collected by an external evaluation team at the conclusion of the summer program; responses were treated as confidential and only aggregate data was provided to the program lead.

Of the 20 faculty members recruited to the program, 17 completed the summer effort, and 13 completed the survey. Of these, eight self-identified as women, and four self-identified as men. Participants' age ranged from 30 to 52. Only 2 survey respondents identified from the College of Engineering, 9 from the College of Arts & Sciences, and 1 from College of Business.

Likert-scale questions asked about perception, community, and engagement. When asked about their perception of makerspaces, survey respondents self-reported that participating in the program had changed their perception of makerspaces for the better (M = 4.4 [out of 5], SD = 0.65). The faculty also reported agreement with making new connections because of participation in the program (M = 4.0, SD = 1.08). Almost half of the faculty respondents also reported that they felt a sense of community (M=3.3 [out of 5], SD=0.94), and felt engaged at the makerspace (M=3.6 [out of 5], SD=1.03). Approximately 12 of the participants rated 5 out of 5 that makerspaces would be beneficial to education.

Open-ended questions asked about motivation and barriers. When asked what motivated attendance, 4 out of the 13 faculty members said that deadlines for their project showcase encouraged them to attend the facility more often. Other motivations cited included being excited to create items and work on personal projects, being able to use specialized equipment, meeting new people and being able to relax.

When asked about barriers to participation, 9 of the survey respondents mentioned having difficulty setting time aside to attend the facility. Others stated that parking inaccessibility, location of the facility, membership cost, hectic work schedule and lack of compatible training hours with makerspace staff were specific barriers to engagement with MakeHaven.

With regards to their likelihood of using the makerspace at the University of New Haven in the future, 6 of the 13 survey participants reported likely to use the space (M = 4.1 [out of 5] SD=1.26); whereas 3 responded indecisive about the likeliness of usage. Overall, faculty indicated that they would like to incorporate the makerspace into their curriculum (M = 4.3 [out of 5], SD = 0.85). Satisfaction with the availability of training and equipment was high (M = 4.5 [out of 5], SD = 0.77 and M = 4.61 [out of 5], SD=0.65, respectively). Though the faculty members were satisfied with the availability of equipment, their comfortability with using equipment was comparatively low (M=3.75, SD=0.75).

B. *Post training survey data from makerspace expert speaker*

The expert speaker seminar and working lunch was hosted by the university's makerspace in partnership with the Department of Engineering and Applied Science Education at the University of New Haven, however, it was broadly advertised to all faculty on campus as an introduction to leveraging the makerspace for their courses. The seminar was attended by 23 people of which two were College Deans, one was a University Associate Provost, and two were the faculty leads on this initiative. The other 18 attendees included 10 faculty from the College of Arts & Sciences and 8 faculty from the College of Engineering. The seminar portion of the event was held in a lecture room not located within nor adjacent to the makerspace. Though many in attendance reported familiarity with the maker movement and the university's makerspace, several had not yet been to the actual space.

Immediately following the seminar, the faculty were invited to a working lunch held at the makerspace. This was an opportunity to see the equipment up close (i.e., not just in

Table 1: Compilation of ideas generated by faculty for creatively leveraging the makerspace resources in support of the learning outcomes of their courses.

Topic / Class	Idea for Potential Integration
Biology	Each student creates a Phylogenetic model to study Biodiversity.
Mechanical Engineering	Build a water heater using a heat lamp.
History	Create propaganda/advertising related to specific historical event (i.e., Olympics)
Public Health	Design and print bumper stickers that communicate public health mnessage.
General Engineering	Build small air-powered turbine to power an electric incandescent lightbulb.
Microbiology	Create a model or game that illustrates concept from class such as DNA supercoiling, gene transfer, mutations, etc.
Psychology / Child Development	Design a *product* (game, toy, book, etc) for a child in a particular developmental stage.
Computer Science	Use simple electronics (e.g., Arduinos) to demonstrate sending messages from sender to receiver.
Chemistry	3D Print Protein & Model of Designed Compound as a way to visualize chemistry.
Communication Practicum	Produce posters/graphics/other to support TV telethon production
Chemical Engineering	Build a fluid flow system integrating sensors and 3D printed components.

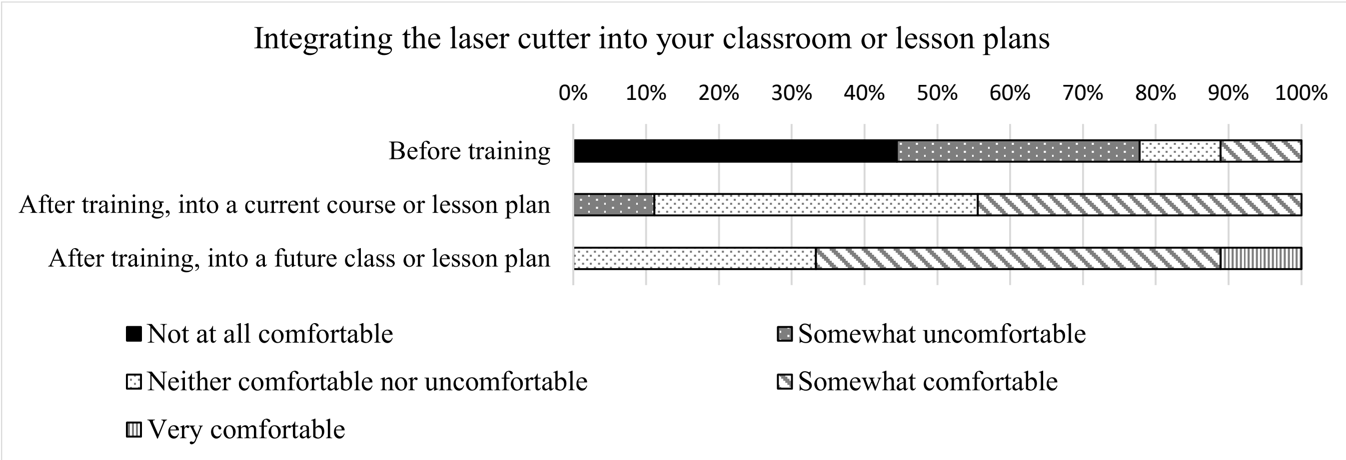

Figure 1: Faculty feedback on comfort implementing the laser cutter into their own classroom experience before and after training

pictures). During the lunch, faculty were encouraged to generate ideas of how they could creatively leverage the makerspace for their courses. The expert speaker, the two faculty leads, and a makerspace student worker were at hand to discuss equipment capabilities, logistical questions, and help ideate potential ways to incorporate the usage of the space in support of their course outcomes.

The faculty were asked to write up the idea they were most likely to pursue on large Post-it™ notes to share with others. Twelve faculty generated and shared ideas, with results including their broad topic shown in Table 1. We note that there were people who joined for the working lunch who had not been able to attend the seminar session.

Following the event, faculty were encouraged to setup appointments for training on equipment or one-on-one time with the support staff to prototype their ideas. Based on the log of projects created or worked in the makerspace, none of the ideas listed in Table 1 have moved forward.

C. Post training survey data from equipment trainings

As shown in Figure 1, the post-training survey from the equipment training on the laser cutter indicated the participants were generally not confident in their ability to implement the laser cutter into a class before the training, but were somewhat more confident in their ability to include the laser cutter into a current course, and much more confident to include in a future course. This increase in confidence suggests that trainings including both pedagogy and equipment instruction may provide the appropriate content needed to facilitate curricular change.

While seemingly positive with general comfort, the qualitative feedback from the faculty and staff indicated they were still uncertain as to exactly how they would implement the laser cutter in their lesson plans. Ideas that were suggested in the post-survey included additional/supplementary activities such as for summer camp activities or student club demonstrations rather than integrating the makerspace (hands-on activities) as an essential component of their curriculum. In particular, the faculty members were unable to see the value of makerspace in regard to their current courses. However, many of the faculty members requested specific equipment-focused training on 3D printing and modeling, potentially as it was easier to see a connection to their course with that equipment. 3D models (in any course) serve a great function in providing students a deeper insight and enriched learning experience. Other requested training included Arduino programming and Carvey (CNC).

D. 3-month followup survey

While immediate intentions are often positive, multiple reasons may exist for why a faculty member may not carry-through with their plans for makerspace implementation. This was even more-so true after a year of curricular impacts due to COVID-19. In order to assess this, an initial follow-up survey was deployed in March 2020, three months after the completion of the last training initiative. A total of 54 individuals were invited to participate in the initial follow-up survey, and 10 completed it for a response rate of 18.5%.

Table 2 shows the various types of follow-up actions an individual had participated in or incorporated from the makerspace were recorded and grouped according to which training or trainings they had participated. Individuals who participated in more than one training were included in both groups. While the number of responses is small, faculty were less-likely to make a personal project in the makerspace (1 response) than they were to visit the makerspace (2 responses total) or to plan a course project (4 responses total).

At the time of the three-month follow-up survey, 4/11 of the respondents had implemented the makerspace into their course and 3 others intended to in the future. Of those that had not yet, two specified that the makerspace did not seem to align with their course content, and two mentioned time limitations. Those that had implemented the project provided examples of their activities, including having students learn how to use the 3D printer and write a reflection (Chemical Engineering), and having students use the laser cutter to create and analyze letterforms (Graphic Design). Faculty were asked to reflect on specific outcomes or behaviors they saw in their students as a result of the makerspace project; a few examples include:

> "It was clear that students were excited, and most of their reflections stated that they enjoyed the project."

Table 2: Faculty engagement after each type of training opportunity

	Participation or Integration with the Makerspace at 3-months			Participation or Integration with the Makerspace at 1 year		
	Visited a Makerspace	Made a Personal Project	Planned a Class Project	Visited a Makerspace	Made a Personal Project	Planned a Class Project
Faculty training on laser cutter	2/4	1/4	2/4	4/5	1/5	3/5
Presentation by expert	1/4	1/4	1/4	4/4	1/4	2/4
Summer makerspace program	0/3	0/3	1/3	2/6	0/6	2/6
Individual Training or Consultations	0/1	0/1	1/1	0/2	0/2	0/2

> "Students were engaged in the project in a different way than other assignments. Made them think about this and future assignments in a more comprehensive way."

All four of the faculty who had implemented projects planned to continue the projects in the future, referencing student enjoyment and improved quality of project deliverables. Faculty requests for future information or training included more hands-on training on other equipment in the makerspace.

E. 1-year followup survey

The three-month survey was distributed two weeks before our institution transitioned to remote instruction for the duration of the semester in response of the COVID-19 pandemic. While many courses in the Fall 2020 and Spring 2021 semester did continue in some modified format including hybrid, flex, or remote synchronous instruction, on-ground instruction was permitted for some courses in the Fall, and expanded to more courses for Spring 2021 as long as classroom capacities followed state guidelines for safety and physical-distancing. On a more positive note, the university opened a new building in Fall 2020, which included a new, larger makerspace for the entire campus community. Thus, a second follow-up survey was distributed in March 2021 to determine if any additional implementations had been achieved, over one year after the completion of the initial training initiatives. Of the 54 individuals who were invited to participate in the final follow-up survey, 14 completed it for a response rate of 25.9%.

The right-most columns of Table 2 show the results of the faculty engagement or implementation of the makerspace for the one-year survey. Seven of the 14 respondents had visited the makerspace, one had completed a personal project, and six had planned a class or course activity to use the makerspace. Five of the individuals had already implemented the makerspace project, with examples including designing a 3D printed component to fit a specific piece of tubing equipment, and then measuring the printed result to test if the result was leak-tight (Chemical Engineering), a soldering-lab (Electrical Engineering), and creating a figure and calculating the volume of the figure when rotated around an axis (Mathematics). An additional six individuals had not yet implemented their activity but intend to. The faculty reflections on student outcomes or behaviors include mentions of concrete examples, student enjoyment, and that the projects challenged and engaged students in ways other teaching may not.

Requests for additional training or additional student training materials that could be distributed directly to students with instructions on how to operate the equipment, summarized policies for using the space for classroom use, and additional in-person refresher courses on the various pieces of equipment.

Of the individuals who had not yet implemented or did not intend to, the most common answer was the COVID-19 pandemic. Some faculty were not aware they could send their students to the makerspace, and others mentioned time concerns relating to the burden of teaching in new modalities or the significant time commitment to create a new activity that would integrate the makerspace.

As an additional question on the Spring 2021 survey, faculty who did implement an activity were asked the extent to which the makerspace student staff or faculty liaisons assisted with the class activity. Table 3 shows results of the staff support question. Most often, staff were consulted during the design of

Table 3: Percentage of faculty implementations in the makerspace that utilized various types of staff support.

Staff were consulted during design of activity	50.0%
Staff trained faculty on equipment prior to classroom implementation	16.7%
Staff provided a classroom demonstration during classroom time	33.3%
Staff supervised students using the equipment during class time	33.3%
Staff supervised students using the equipment outside of class time	33.3%
Staff used equipment to print student design files	16.7%

the activity (3/6), while staff were also used to provide classroom demonstrations of the equipment and/or supervise student during or outside of class time. In one implementation, the makerspace staff were the individuals who took the student designs and printed them on the 3D printer rather than the students printing them themselves.

IV. Discussion

The survey-based results hint at increased student engagement as perceived by the faculty. This is in alignment with findings reported by Lenhart *et al*. and Bouwma-Gearhart *et al*. [1, 12]. Due to small numbers of faculty respondents, we are hesitant to generalize that any particular type of training was more or less likely to result in faculty implementation of a makerspace activity into their course. However, the survey responses suggest that those faculty that participated in the individualized equipment training and pedagogy discussion or the makerspace expert and pedagogy discussion were more likely to engage with the makerspace themselves after the event and implement the makerspace into their course. However, this may not tell the full story. Even though it appears that only 0/3 and 2/6 respondents in the follow-up surveys who participated in the summer makerspace event had visited the makerspace since their training, this may be for a few reasons. It is possible they did not need to explore the makerspace, consult staff on how to use the equipment, and felt comfortable planning their activity because they had an entire summer to use a nearby makerspace themselves. As another factor, all six of the faculty who had been involved with the summer program and responded to the survey were non-engineering faculty. Thus, they may not have been aware the new makerspace was open as the makerspace is in a building directly-attached to the engineering building that they may not walk by to see if it is open yet.

Projects are frequently found within engineering curricula, and our faculty frequently leverage the use of their discipline specific labs and technicians, whereby students tackle the build/test of their project outside of class time. As such, it may be the case that faculty within engineering assign projects but do not see the need to coordinate or leverage the makerspace as their students could use the engineering machine shop or the instrumentation labs. However, as students learn about the capabilities of the equipment and resources in the makerspace, we are seeing more of them resort to using the space for their projects even if not formally coordinated with the space. On the contrary, we've noticed that faculty from non-engineering disciplines may not assign hands-on projects as often, which aligns with the previous results from Dahal that integration may fail due to perceived lack of alignment [2]. When non-engineering faculty do engage the makerspace, they prefer to bring their class into the space for a working session. Frequently, when planning, their most asked questions pertain to cost of supplies or cost of use.

The diffusion of innovation framework suggests that faculty will require both formal knowledge gains and a decision to try out the space, before formally committing for long-term change to the innovation (in this case, inclusion of the makerspace). The faculty makerspace membership aligns with stages of persuasion and decision, allowing faculty to choose to learn more about the makerspace by being in the space, which may or may not influence their own classroom implementations. The results of positive opinions and inclusion in education suggest that this training model is a success for persuasion, but may not always result in the positive decision to implement (potentially due to more knowledge of if the innovation is appropriate for the coursework that they teach. The expert speaker and workshop event targeted the knowledge and persuasion stages, but again, due to the lack of implementation of the ideas from Table 1, the faculty attending this style of workshop may not have enough information to both make a decision and be willing to attempt a trial in their classroom. The equipment and pedagogy focused laser cutter training appears to have the most success in convincing faculty to make a decision and trial the makerspace classroom innovation. However, this may indicate faculty had already passed the knowledge stage and were interested in exploring the decision and trial stage from their sign-up and participation in this training style.

The efforts described here are by no means all encompassing. We are aware of faculty on our campus that have been trained by participation in external efforts, including a few that have participated in *B-FAB* [5] and *Making with Purpose* workshops [6]. We are also aware of faculty that have been trained in the type of equipment available in the makerspace, either by prior experiences (e.g., wood shop tools) or self-taught and driven by personal interests e.g., sewing and embroidery. The follow-up surveys we conducted were anonymous, and as such we cannot isolate the responses for those that have engaged with multiple training efforts.

Additionally, the data reported here does not represent all those who are utilizing and incorporating the makerspace into their curriculum. Anecdotally, it would appear that faculty from non-engineering programs are more likely to engage with the resources of the makerspace. However, it may be that pressure to ensure the Makerspace is truly a campus-wide resource may be presenting increase motivation for non-engineering programs to leverage the makerspace. Research on faculty development success (defined as having faculty adapt ideas from training into their classroom implementation) has suggested that engineering faculty are more likely to participate in and adapt pedagogy shared from engineering faculty than from broader audiences [13]. Thus, even though our goal is to get all faculty to engage in the makerspace, some discipline-based recruiting and training may be necessary.

The results of this study should be considered preliminary due both to the small sample sizes of survey responses as well as the emphasis on a single-university data collection and analysis model. Potentially even more significant was the impact of the COVID-19 pandemic on this study, impacting faculty time, forcing strict regulations on in-person teamwork settings and equipment sharing, and reducing the number of in-person instruction opportunities on our campus. Multiple faculty referenced the broad impacts of the pandemic as the main reason they had not yet implemented a makerspace activity. In the future, we hope to continue to explore how best universities can encourage faculty to adopt and integrate the makerspace into their course with additional follow-up surveys of both prior-trained participants that may reflect broader adaption as the impact of the pandemic on teaching lessens over time.

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