"Teams Teaching Engineering": A flexible hands-on project promoting makerspace usage in large introductory lecture classes

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Abstract

Though experiential learning and hands-on “making” projects can encourage development of an entrepreneurial mindset and increase student engagement, such activities are often considered incompatible with larger lecture classes with over 50 students and no lab sections.

This paper describes an open-ended project called “Teams Teaching Engineering” that can be scaled up or down in complexity and is adaptable to a wide range of classes. In its most simple form, it can be used as a large homework assignment, where student teams build a visual aid illustrating a class concept, use it to teach someone outside the team, then write about what they have learned from the process. This simple version was successfully implemented in four semesters of a statics class with over fifty students and in a one-credit Introduction to Aerospace Engineering class with over 125 first-year students. After positive feedback, the Introduction to Aerospace assignment was expanded into a more elaborate semester-long project that added makerspace visits and an essay where students reflected upon the opportunities these spaces might offer to cultivate an entrepreneurial mindset. Student surveys captured attitudes about the project and the university making facilities, and indicated that a large majority of the students were more likely to use the making facilities in the future because of the semester project. Student reflective essays also indicated that the students believed that making spaces added enormous value to the university and supported cultivation of the entrepreneurial mindset, specifically promoting curiosity, making connections, and creating value.

The “Teams Teaching Engineering” project may provide an experiential learning opportunity for classes that otherwise may not include a hands-on project while motivating incoming students to explore and use the university makerspaces and other fabrication facilities. When combined with a student surveys and a reflective essay assignment, it can also provide useful insights on how students perceive both the team project and the university’s makerspace ecosystem.

Background and Motivation

Engineering educators, industry partners, and other stakeholders believe that the next generation of engineers need more than just technical knowledge- they must have a diverse set of professional skills to function in a rapidly changing workplace. This view has been captured by several ASEE reports on Transforming Undergraduate Education in Engineering (TUUE) [1], [2], and in an Engineering Competency Model developed by the American Association of Engineering Societies and the US Department of Labor [3]. Many professional skills considered important in today's rapidly changing environment are also considered important in entrepreneurship. An "Entrepreneurial Mindset" (EM) has been defined as a set of cognitive behaviors that focus on recognizing opportunities and creating value in any context, not just as part of a new business; and some have argued that cultivating EM in engineering undergraduates can benefit individuals, their employers, and the larger society [4]. Entrepreneurially Minded Learning (EML) is an emergent pedagogy that attempts to cultivate this mindset in engineering undergraduates by emphasizing discovery, opportunity identification and value creation through open-ended problems that tie to real-world applications [5]. In this paper, EM follows a framework used in the Kern Entrepreneurial Engineering Network (KEEN), which emphasizes curiosity, connections and creating value [6].

Active learning and hands-on projects, which are emphasized in EML, have been shown to improve student performance and engagement [7] and some researchers have reported a positive impact on retention [8]. ASEE's Phase II TUUE report indicates that engineering undergraduates believe that more open-ended problems and design projects are needed throughout the curriculum and should be available in extracurricular activities [2].

One tool that universities are turning to facilitate hands on projects is academic makerspaces, which may reduce barriers to the use of student projects in classes and provide more opportunities to include EML activities in the curriculum that include prototyping and fabrication of a physical product. The concept of the university maker space is a relatively new concept, but research and interest in academic makerspaces has grown in recent years [9], [10], [11]. Most students use academic makerspaces to work on personal projects, engage in organized co-curricular activities, or complete hands-on projects required by their curriculum. The spaces also provide the potential to provide a sense of community within the larger university campus and allow a forum for creative expression.

Though many believe academic makerspaces have the potential to transform the educational experience [10], it can be difficult to implement class projects that involve fabrication, especially in core classes that have over 50 students and no lab sessions. Traditional faculty who do not teach engineering design may hesitate to ask students to fabricate a physical product because of their own lack of familiarity with makerspaces. Furthermore, even those motivated by the idea of entrepreneurially minded learning may see a large lecture-based class as inhospitable to any hands-on project. Furthermore, though academic makerspaces are freely available to students for extracurricular projects, not all students take advantage of them. Some students may already be experienced makerspace users; others may be eager to learn, but lack the confidence or initiative

to seek out what makerspaces have to offer. For example, Florida Tech has four high quality academic "making" facilities and free training on how to use the equipment available to the campus community, but only a fraction of students take advantage of them. More class projects with EML themes early in the curriculum may encourage future makerspace usage for co-curricular activity, better senior design experiences and an overall increase in self-efficacy.

The work reported here attempts to address these issues in an incremental fashion. The first section of the paper describes a simple team project that could be used by faculty as a first "small step" towards increasing the EML themes and active learning in an otherwise traditional class environment with over 50 students. What makes this useful as a curricular tool is the fact that the basic idea can be used in nearly any class and its modest scope allows faculty with no previous experience with EML or active learning to try it without a serious time investment.

Subsequent sections of the paper describe an expanded semester-long version of the project and results from student surveys and feedback. One of the goals for the semester project is to increase student engagement in the makerspaces beyond what is required for class assignments. As described here the project was designed for engineering students in their first semester of college, but the project could be tailored for use later in the curriculum. By linking class projects to university makerspaces, both faculty and students can draw upon the experienced staff and training opportunities many makerspaces prove to the campus community.

Small steps towards EML and active learning: the "Teams Teaching Engineering" Project

The Teams Teaching Engineering project was first used in a statics class with over 50 students and was repeated for four semesters. In this early version (called "Teams Teaching Statics") the scope was smaller and the project did not require students to interact with makerspaces or use CAD tools. In its most basic form, student teams created a visual aid of a statics concept and used it to teach someone outside the team. Students were allowed to pick their own teams (3-4 individuals), and the instructor would only engage if people were having difficulty finding someone to work with. The graded deliverable was a short report describing the statics concept they were teaching, the visual aid they created, the process of teaching someone using the visual aid, and what they learned from the experience. Students were required to include photos of the visual aid and the teaching process in their report, but did not have to turn in their physical product. Some students offered up their creations anyway, and several of the better ones were used as teaching tools for future classes. Grading was generous- near full credit was awarded for completion of all steps of the assignment, and extra credit was awarded for exceptional efforts. The project was not heavily weighted- it was part of the homework grade, with double the weight of a typical assignment. Students with D or F class averages that could not find team partners were given an alternative assignment (e.g., copying example problems from the text). For some semesters, students were also required to complete a "statics photo safari" where they took pictures of objects on campus, then draw free body diagrams and identify support reactions.

This simple version of the teaching project was created in 2016 by an inexperienced professor (the author) attempting to inject more active learning in an otherwise traditional lecture class. It was a first attempt to implement EML in the classroom after being exposed to the concept and no attempt was made to quantify the success of the project, but it appeared to meet the modest goals set for it. The open-ended nature of the assignment provided a welcome change from standard homework problems and students seemed energized by the project. From an instructor standpoint it was relatively straightforward to implement, and because the assignment was short, generously graded, and included student photos, grading the student reports was much more enjoyable than a typical assignment.

Based on its success in the statics classroom, a similarly scoped project was added to the Aerospace Engineering (AE) curriculum in Fall 2018. At Florida Tech all first-year AE students take a one-credit "Introduction to Aerospace Engineering" (IAE) class in their fall semester, then in the spring they take a two-credit "AE Practicum" lecture and lab that teaches design skills. Before 2018, it was assumed that a hands-on project wasn't feasible in the fall IAE class due to the limited contact hours (one credit hour; weekly lecture) and relatively large class size (over 125 students in one auditorium). Unlike in statics, students were randomly assigned to groups using the CANVAS course management software, reducing the requirement for first year students to find partners in such a large class. In an anonymous survey completed by 53% of the class, 90% of respondents indicated they liked the open-ended nature of the project and 96% considered hands on learning important to engineering education, which was consistent with the student perspectives captured in the ASEE TUUE Phase II Report [2]. Students were asked for suggestions on how to improve the project, and they responded with several constructive suggestions and a strong preference for more hands on projects. Based on these encouraging results, an expanded semester-long version of the project was implemented the next year (2019).

2019 Semester-long Project with Makerspace Engagement: "Teams Teaching Aerospace"

Goals for 2019 Semester Project. One major goal for the expanded "Teams Teaching Aerospace" project was to help students taking IAE (mostly first-year students) to become more familiar with the making facilities on campus available for student personal projects and class assignments. At Florida Tech, "making facilities" were defined to be a machine shop, a digital scholarship lab in the library with Virtual Reality (VR) software and 3-D printing services, a large multi-use student design center, and a traditional makerspace and electronics lab. (To avoid confusing the students, the term "makerspace" was only used to refer to the facility with that name). Though free training was available at all four sites, less than 29% of the 2018 IAE students reported that they used the school facilities to complete their projects. Another major project goal was to better prepare students for next semester's AE Practicum projects by giving them some fabrication experience and to provide opportunities to practice professional skills in a team setting. Finally, there was interest in surveying student attitudes about the project and the university's making facilities. Would first-year students react negatively to a relatively complex team project in a one-semester class? What level of scaffolding is needed for student teams to

complete a simple CAD model before formal instruction is offered? Could moderate exposure to the making facilities in an open-ended class project encourage students to use them for personal projects in the future? Also, what were student perspectives on the linkage between making facilities and elements of the entrepreneurial mindset- cultivating curiosity, making connections, and creating value? If the project proved effective in the first-year aerospace sequence, it might be adaptable to other engineering programs and of interest to the general engineering education community.

2019 Project Structure. The project was launched in week 4 of the Fall 2019 semester, a preliminary report was due in week 7, and the final report and two PowerPoint slides were due in week 15. All requirements for both the preliminary and final reports were identified at the start of the project.

A majority of the class had identified a preference to be randomly assigned in teams in order to meet new people, so CANVAS was used to form 33 teams of 3-4 people each. For the preliminary report, students visited and wrote about visits to the four different campus fabrication facilities, describing how they could be used for classwork or personal projects. They were also asked to work as a team to come up with a plan to make an inexpensive visual aid to illustrate an aerospace concept or emerging trend. To reduce social loafing, "selfie" photos of each team member were required as part of the site visits, and each student had to write and identify authorship of at least one part of the report.

In the final report, the student team was required to include a screenshot of a CAD model of at least one part of their visual aid, a description of their fabrication process, a photograph of their final product, pictures of the team using the visual aid to teach someone the aerospace concept or emerging trend, and lessons learned. Aerospace freshmen are not taught CAD until the second semester (in Aerospace Practicum), but in an early survey completed by 45% of the class, 54% of the respondents indicated they had at least minor exposure to some form of CAD software. Because each team had four members, the odds of at least some CAD experience on each team was high, and the students were told that help was available in the campus fabrication facilities. Students could use whatever CAD software they wished, but Autodesk Fusion 360 was recommended for those teams who had no previous CAD experience.

There was not enough contact time to allow 33 teams to brief their project, but the instructor showcased some of the more notable projects on the last day of class using the student PowerPoint slides submitted with the final assignment.

After the project was complete, each student was also assigned a reflective essay about makerspaces and the entrepreneurial mindset, and were given an opportunity to complete an anonymous survey on the assignment. A small amount of extra homework credit was awarded to students who completed the survey and gave informed consent for their reflective essays to be used in research.

Student Survey Participation and Structure. The 2019 class included 127 students averaging 19 years old, 80% male and 20% female. Most were first year students, but older transfer students or those changing majors into aerospace also took the class. Table 1 provides statistics for those who completed the survey.

Table 1: 2019 Student Survey Participation Statistics

Class size: 127; **Particpation rate:** 67%		
Academic Class	number of respondents	Percentage of total
First year student	69	81%
Sophomore	7	8%
Junior	7	8%
Senior	1	1%
Other	1	1%
Total	85	100%

Gender	number of respondents	Percentage of total
Female	23	27%
Male	62	73%
Total	85	100%
Residency		
U.S.Citizen	75	88%
International Student	9	11%
Green Card/Other	1	1%
Total	85	100%

In the survey, the term "making facilities" was defined as four distinct locations on campus visited by student during the preliminary phase of the project (machine shop, digital scholarship lab, student design center and traditional makerspace). Scoring on the Likert scale questions ranged from 1 (strongly disagree) to 6 (strongly agree) and an average score for each question is reported in the tables below. One open-ended question asked for suggestions on how to improve the project.

Table 2: Survey Responses: Student Attitudes about Hands on Projects and making spaces

In general, I think engineering classes should include "hands on" projects to help students learn.			
		Respondents	Percentage
1	Strongly disagree	0	0%
2	Disagree	0	0%
3	Somewhat disagree	1	1%
4	Somewhat agree	5	6%
5	Agree	22	26%
6	Strongly Agree	57	67%
	Total	85	100%
	Average	**5.59**	

The university "making" facilities support hands on projects helpful for student learning			
		Respondents	Percentage
1	Strongly disagree	0	0%
2	Disagree	1	1%
3	Somewhat disagree	0	0%
4	Somewhat agree	11	13%
5	Agree	32	38%
6	Strongly Agree	41	48%
	Total	85	100%
	Average	**5.32**	

Results in Table 2 indicate that 99% percent of students agreed at some level that that engineering classes should include hands on projects (average 5.59/6), and that the university facilities supported projects helpful for student learning (average 5.32/6).

Table 3. Survey Responses: Student attitudes about "Teams Teaching Aerospace" project

I liked the flexibility of the project- the fact that our team could decide what product to make.			
		Respondents	Percentage
1	Strongly disagree	0	0%
2	Disagree	1	1%
3	Somewhat disagree	0	0%
4	Somewhat agree	11	13%
5	Agree	30	35%
6	Strongly Agree	43	51%
	Total	85	100%
	Average	**5.34**	

I liked the fact that teams were randomly assigned and I met new people in the class.			
		Respondents	Percentage
1	Strongly disagree	5	6%
2	Disagree	9	11%
3	Somewhat disagree	3	4%
4	Somewhat agree	20	24%
5	Agree	28	33%
6	Strongly Agree	20	24%
	Total	85	100%
	Average	**4.38**	

The project made me think more deeply about some technical aspect of aerospace engineering.			
		Respondents	Percentage
1	Strongly disagree	2	2%
2	Disagree	3	4%
3	Somewhat disagree	3	4%
4	Somewhat agree	21	25%
5	Agree	28	33%
6	Strongly Agree	28	33%
	Total	85	100%
	Average	**4.81**	

I learned more about the university's "making" facilities as a result of this project.			
		Respondents	Percentage
1	Strongly disagree	3	4%
2	Disagree	3	4%
3	Somewhat disagree	1	1%
4	Somewhat agree	12	14%
5	Agree	33	39%
6	Strongly Agree	33	39%
	Total	85	100%
	Average	**4.98**	

The four questions in Table 3 indicated favorable responses to the project and suggested that it met its objectives of exposing students to the fabrication facilities on campus. All but one student liked the open-ended nature of this particular project (average 5.34/6) and 92% learned more about the university making facilities as a result of the project (4.98/6). Most felt the project made them think more deeply about the subject (4.81/6). The survey also had a field for students to suggest improvements for the project. One student requested a heavier research emphasis on the aerospace concept being demonstrated in the visual aid. Another student wanted an opportunity to present to the class. Others identified student procrastination as a problem and thought more increments in the project would help combat it. Though a majority liked the fact that teams were randomly assigned (average score 4.38), some did not. One student commented that by the time the project was launched, they were already starting to meet people they would like to work with, and the project should be launched earlier than week 4 of class.

Survey responses in Table 4 below suggested that the project appeared to be motivating students to take advantage of university making facilities, with 93% of students indicated some level of agreement that they were more likely to use the making facilities in the future because of the project (average 4.85/6). The same percentage indicated they were at least somewhat likely to use the facilities for a personal project in the next 1-2 years (average 5.13/6).

Table 4: Survey Responses on future use of university makerspaces

I am more likely to use the university "making" facilities in the future because of the "Teams Teaching Aerospace" project.			
		Respondents	Percentage
1	Strongly disagree	2	2%
2	Disagree	3	4%
3	Somewhat disagree	1	1%
4	Somewhat agree	16	19%
5	Agree	41	48%
6	Strongly Agree	22	26%
	Total	85	100%
	Average	**4.85**	

I believe my teammates are more likely to use the university "making" facilities in the future because of the project. (Answer for other teammates, not for yourself).			
		Respondents	Percentage
1	Strongly disagree	1	1%
2	Disagree	1	1%
3	Somewhat disagree	6	7%
4	Somewhat agree	19	22%
5	Agree	40	47%
6	Strongly Agree	18	21%
	Total	85	100%
	Average	**4.76**	

I like the idea of using the university "making" facilities for personal projects.			
		Respondents	Percentage
1	Strongly disagree	1	1%
2	Disagree	0	0%
3	Somewhat disagree	1	1%
4	Somewhat agree	6	7%
5	Agree	33	39%
6	Strongly Agree	43	51%
	Total	84	100%
	Average	**5.37**	

I am likely to use the university "making" facilities for a personal project in the next 1-2 years.			
		Respondents	Percentage
1	Strongly disagree	1	1%
2	Disagree	2	2%
3	Somewhat disagree	3	4%
4	Somewhat agree	14	16%
5	Agree	24	28%
6	Strongly Agree	41	48%
	Total	85	100%
	Average	**5.13**	

Survey responses: "project averse" students. As seen in Table 5, eight of 85 students (9%) reported at least a mild tendency to avoid hands-on projects, agreeing with the statement, "In team projects that include making something, I try to avoid the hands on part of the project."

Table 6 shows the student responses, gender, and academic rank of those whose survey results indicated a tendency to avoid hands-on projects, and how they responded to some of the other key questions in the survey. Limited conclusions can be drawn from such a small sample size, but it appears that at a majority of these "project averse" students learned from the project and may be motivated to use the making facilities in the future. Only one of these eight students was female, and her academic rank as a junior may have been a factor in her answers.

Table 5: Student that avoid hands-on projects

In team projects that include making something, I try to avoid the "hands on" part of the project.			
		Respondents	Percentage
6	Strongly disagree	41	48%
5	Disagree	25	29%
4	Somewhat disagree	11	13%
3	Somewhat agree	6	7%
2	Agree	1	1%
1	Strongly Agree	1	1%
	Total	85	100%
	Average	**5.13**	

Table 6: Survey Responses from students that avoid hands on projects: future makerspace usage

In team projects that include making something, I try to avoid the hands on part of the project.	academic class	gender	I learned more about the university facilities as a result of this project. (Class Average= 4.98)	I am more likely to use the university making facilities in the future because of the project. (Class Average=4.85)	I am likely to use the university making facilities for a personal project in the next 1-2 years.(Class Average= 5.13)
1.Strongly Agree	Freshman	Male	6. Strongly Agree	6. Strongly agree	6. Strongly agree
2. Agree	Junior	Female	3. Somewhat disagree	2. Disagree	2. Disagree
3. Somewhat Agree	Freshman	Male	5. Agree	5. Agree	6. Strongly agree
3. Somewhat Agree	Freshman	Male	5. Agree	5. Agree	2. Disagree
3. Somewhat Agree	Freshman	Male	4. Somewhat agree	2. Disagree	3. Somewhat disagree
3. Somewhat Agree	Freshman	Male	6. Strongly Agree	1. Strongly disagree	6. Strongly agree
3. Somewhat Agree	Freshman	Male	5. Agree	5. Agree	6. Strongly agree
3. Somewhat Agree	Freshman	Male	5. Agree	6. Strongly agree	6. Strongly agree
Category Averages			4.88	4.00	4.63

Survey Responses: Situations where students would be likely to use making facilities.
Tables 7 and 8 report responses to the question, "In what situation would you be most likely to use a "making" facility? Rank the following from 5 (most likely) to 1 (least likely)." Two students did not answer the question, and others did not use the expected 5-4-3-2-1 ranking, instead marking multiple options as more or less likely. Though individual motivations varied, class totals suggested students were most likely to use a making facility for a class project, even if using the facility was not a firm requirement (Table 7). The second preference was working on a personal project or working with a group of friends, and organized co-curricular activities or optional school competitions came in third.

Table 7 Survey Responses: Situations where all students are likely to use making space

All Student Responses 83 total: 61 males; 22 females	Most Likely		Second Most Likely		Third Most Likely		Less Likely		Least Likely		Total Points	%
In what situation would you be most likely to use a "making" facility?	# responses	5 points each	# responses	4 points each	# responses	3 points each	# responses	2 points each	# responses	1 point each		
Class assignment where using the makerspace is an option, but not required.	43	215	13	52	17	51	8	16	2	2	336	25%
A personal project of my own choice	22	110	22	88	23	69	9	18	7	7	292	22%
A project that I am working on with a group of friends (not class, club, or competition)	15	75	26	104	20	60	15	30	7	7	276	21%
An organized co-curricular activity (student club, dorm event)	10	50	16	64	13	39	24	48	20	20	221	17%
An optional school competition	10	50	14	56	13	39	14	28	32	32	205	15%
									Total		1330	100%

Table 8 show results for just the 22 female students completing the survey, but the trends were the same as the general population. The females showed a slight preference for competitions over other co-curricular activities and a slight preference for working with a group of friends over working alone on a personal project, but the differences were not significant.

Table 8: Survey Responses: Situations where female students are likely to use a making space

Female Student Responses (22 Students Total)	Most Likely		Second Most Likely		Third Most Likely		Less Likely		Least Likely		Total Points	%
In what situation would you be most likely to use a "making" facility?	# responses	5 points each	# responses	4 points each	# responses	3 points each	# responses	2 points each	# responses	1 point each		
Class assignment where using the makerspace is an option, but not required.	8	40	5	20	7	21	2	4	0	0	85	24%
A project that I am working on with a group of friends (not class, club, or competition)	5	25	9	36	4	12	1	2	3	3	78	22%
A personal project of my own choice	6	30	4	16	6	18	4	8	2	2	74	21%
An optional school competition	4	20	5	20	5	15	3	6	5	5	66	19%
An organized co-curricular activity (student club, dorm event)	0	0	4	16	4	12	8	16	6	6	50	14%
									Total		353	100%

Planned changes to the 2020 implementation of "Teams Teaching Aerospace" project.
Based on the positive survey results and student feedback, the "Teams Teaching Aerospace" project will be repeated in 2020 with only minor changes. First, the project will begin earlier in the semester to allow the student groups more time to connect and get to know each other. Second, the project will include three parts: the makerspace visits, the project idea, and then the final report. Breaking up the preliminary report into two parts should help to minimize the impact of any early procrastination and delays in group formation, since describing the makerspace visits is an easy first step- much easier than coming up with the project idea. The final report will remain unchanged. The other suggested changes (including a presentation element, raising expectations on research) might work for a different classroom environment, but were not considered feasible for this class.

Student Essays on Making Facilities and the Entrepreneurial Mindset.

After students completed the team project, they were asked to individually complete a mandatory reflection assignment intended to get their perspectives on the connection between university making facilities and the three C's of the entrepreneurial mindset. The assignment included three open-ended questions:

- How do you think "making" facilities promote curiosity in students?
- How do you think "making" facilities contribute to your ability to make connections?

- What value to you think that "making" facilities provide on university campuses?

After the assignment was submitted, students were given the option to earn a small amount of extra credit if they provided informed consent for their essays to be used in research, and sixty students agreed to let their essays be used (47% of the class total).

These student essays provided a fascinating window into how students perceive the connection between academic making spaces and the entrepreneurial mindset, and the high value students at Florida Tech placed on these facilities. Figure 1 shows a Cirrus word cloud derived from the collective essay responses, and general themes associated with each question are described below, with supporting quotes from student essays provided in italics.

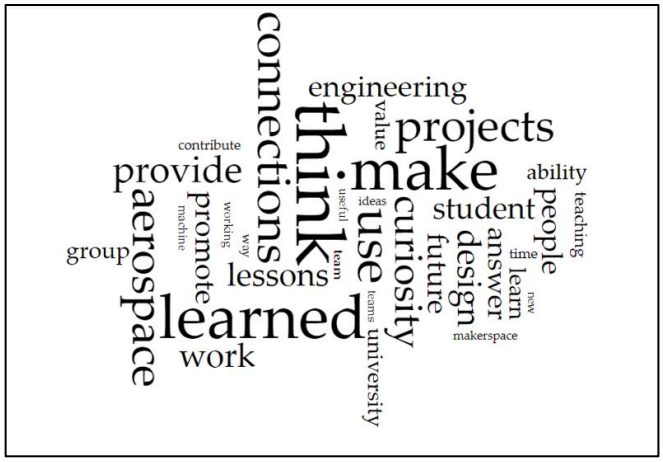

Figure 1: Cirrus Word Cloud of Essay Responses

How "making" facilities promote curiosity in students. Over half of the student essays (53%) noted that availability of diverse tools and techniques promoted student curiosity. *"Providing students with a tool will naturally cause them to be curious how to use it."* Another student noted, "*It's a form of a domino effect. Being exposed and learning about one thing feeds the curiosity and allows students to expand their abilities beyond their original intentions."*

Others felt the opportunity to work on unstructured personal projects promoted creativity and curiosity. "*There is little pressure to perform or prove oneself, so students can just learn, play, and create… Personally, these facilities feel like the workshop I wish I had at home and having it here is just as good." "The overall atmosphere of these facilities put students in a logical and curious mindset. Curiosity and creativity are commonly found when a diverse field of ideas are concentrated into a small space."*

How "making" facilities contribute to making connections. When asked about how spaces support students making connections, 77% of the student essays mentioned the opportunity to meet and interact with other students, including those from other engineering disciplines; 48% mentioned engaging with staff and faculty.

"Making facilities create common locations for people to meet across disciplinary fields."
"Making facilities could allow connections possibly through student activity… turning into cool group projects for interesting ideas to combine, allowing all the group members inside it to grow."

"Making connections is a huge part of life that gets you places... You can make a lot of friendships with other students and faculty in all of these locations because everyone is willing to help or learn more."

A surprising number of comments indicated an understanding of the importance of professional networking. "*Some faculty members have outside connections and when [it is] time to apply for internships may put in a good word for you; meanwhile, the students there are also most likely to have found internships already and can lend advice on applying for them*."
"Making facilities enable students to collaborate on projects, brainstorm ideas, and understand industry standards. Students are able to network with each other and form lifelong professional connections."
A few of the essays discussed the connection between classroom learning and the physical world. Others addressed the connection between making and engineering skills useful for employment. "*Making facilities contribute to my ability to make connections because they give me the chance to see how different concepts relate to each other in the real world... Hands-on experiences teach a more practical and complete understanding than classroom learning alone."*

As seen in the quotes above, students value making spaces as a creative environment for students of different backgrounds to develop connections through unstructured activities, but also to make professional connections and build skills to help their careers.

The value of "making" facilities on university campuses. Student answers to the question, "What value to you think that making facilities provide on university campuses?" reflected both personal and professional themes.

Making facilities provide a sense of entrepreneurship, a sense of self-confidence, and a sense that a university is more than a school with homework, classes, and tests. These making facilities are my favorite places to be on campus… If I was ever bored on campus, I can go to the making facility, relax, and be productive, while still being creative. Another great aspect of making facilities are the other people you interact with. The conversations you have, the things you build, or the laughs you share at the place is what makes my day.

I think this may be some of the most important things a university should do. If we didn't have the facilities, we would be so limited in what we can do and learn that when we get real jobs, we might not have the experience that we need to do our job which these facilities provide.

The facilities bring a sense of fun and innovation to the university. They are a great resource that helps to promote and motivate scholarship within the students… These spaces help students to bring their ideas to life.

Quite possibly the best advantage of the "making" facilities is that there is absolutely nothing to lose. The class/ seminar/ lecture is included in tuition, so might as well make the most of the experience.

Also knowing that everyone at all of the facilities here is willing to help others if they have issues with something or a problem that they don't know how to fix really provides a sense of contentment and feeling welcomed.

But, most importantly, they provide a learning opportunity for students to explore how to use machinery and make their products come to life, which gives them the advantage over other students who were not exposed to those opportunities.

The quotes from the student essays reflect a diverse range of perspectives about the value of making spaces and their connection to the entrepreneurial mindset, but the enthusiasm expressed is consistent. Seeing making spaces as a welcoming space for students to make connections, cultivate curiosity and create value not only supports EML goals, but it also addresses traditional university concerns associated with recruitment, retention and persistence in engineering.

Conclusions and Forward Work

In both its simple and expanded forms, the "teams teaching engineering" project provides an opportunity to increase active learning in conventional lecture classes of greater than 50 students that may be otherwise inhospitable to a hands-on project. In its simple form, it may interest faculty who want to inject more EM content and active learning into an otherwise traditional lecture class, but are unsure where to start and want to limit their exposure on their first attempt. It its expanded form as a semester-long project, it may be a useful tool to introduce first-year students to university makerspaces and fabrication facilities. In student surveys, 93% of students indicated some level of agreement that they were more likely to use the making spaces in the future because of the project. Additional insights were obtained from student essays that asked students to reflect upon the opportunities these spaces might offer to cultivate an entrepreneurial mindset. The reflective essays indicated that students perceived the making spaces as adding enormous value to the university, that the wide range of equipment existing in spaces strongly promoted student curiosity, and that the environment provided valuable professional networking opportunities and promoted connections between students, faculty and staff.

One area of forward work is to refine the project to develop robust curriculum "tools" that can be used in other programs and at other universities to promote makerspace usage. This will be shared through the Kern Entrepreneurial Engineering Network and published on the Engineering Unleashed website [7]. In addition to the team project itself, qualitative analysis methods may be used to analyze the results of the reflective essays, which provided valuable insights on how students perceive a university's makerspace ecosystem.

A second area of forward work involves the development of a longitudinal study of the 2018 and 2019 aerospace engineering freshmen cohort at Florida Tech, with a focus on their makerspace usage, retention to the second year, persistence in engineering and graduation rates. If successful strategies are developed to help aerospace engineering students persist and succeed, other disciplines may benefit.

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