B-Fab: Cultivating Student Learning in the Makerspace through Faculty Development

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Makerspaces offer broad opportunities for including entrepreneurial activities, physical prototypes, and demonstrations in an array of courses and co-curricular activities than was previously possible. It can be intimidating, however, for those who are typically in an instructional role to adopt the role of learner and get themselves trained in the makerspace. Faculty may also be unfamiliar with the appropriate pedagogies for assigning student work in the makerspace, which tend to be active, inductive, and student centered, such as entrepreneurially-minded learning (EML) and problem/project/product-based learning (PBL). To make effective use of the makerspace in class, it's helpful to offer simultaneous support in both the technical training and pedagogical design. "B-Fab," the Bucknell Fabrication Workshop is a summer technical and pedagogical workshop for faculty and staff that aims to boost faculty and staff comfort within the makerspace and to coach participants in the design of good EML/PBL experiences within the makerspace.

This paper discusses the implementation of the three-day workshop, the topics addressed, and the outcomes. In its three years of existence, 50 people have participated, and generated nearly 30 new or substantially expanded assignments or outreach activities that have been shared as KEEN "Cards." Initial qualitative analysis of these cards suggests that the workshop is effective at improving faculty and staff comfort using the makerspace, expanding faculty adoption of EML/PBL, and, ultimately, benefiting students by encouraging adoption of more effective and engaging educational practices.

Introduction

Engineering students benefit from active, collaborative, and problem-based learning (PBL) experiences (1–3). The proliferation of campus Makerspaces creates broader possibilities for active learning as well as cultivation of life-long learning, design-thinking, and other benefits associated with "making"(4–6). Campus Makerspaces generally seek to support the scholarly, educational, and social missions of their home institutions, but their adoption for coursework is not automatic. Without some mechanism to introduce potential student and faculty users to the Maker Space, the space's capabilities may go unharnessed by a significant fraction of potential users.

B-Fab - the Bucknell Fabrication workshop - was initially created as an immersive experience for students to learn the capabilities of tools available through the campus makerspaces in the context of product design. After several offerings to students, demand for a similar workshop from faculty and staff lead the team to switch focus. It was clear there was some level of faculty and staff curiosity about how to use the Makerspace, but that it was somewhat intimidating for faculty to "jump in" and learn the tools themselves. In addition, while faculty had a notion of how they might use a Makerspace for student projects, many felt reluctant to assign such projects without direct experience themselves. Our solution was to re-imagine B-Fab as a faculty and staff experience that empowers participants to innovate in the classroom and provide richer, design- and project- based entrepreneurially-minded experiences for their students, exponentially increasing the impact of the workshop experience.

The primary goal of the B-FAB program is to provide faculty and staff with basic instruction in various fabrication techniques available in Makerspaces on their campus through skill-building projects so that they apply these techniques in the courses that they teach. Initially supported by the Kern Engineering Education Network (KEEN), this workshop provided specific instruction and practice in maker tools as well as foundations of entrepreneurial-minded learning (EML) (7).

The skills and projects included in B-FAB are intended to motivate participants to integrate rapid fabrication technologies into some aspect of their teaching or research, thereby impacting students. Participants practiced CAD, 3D printing, electronics, and laser cutting, as well as learning how to implement EML through problem-/project-/or product-based learning. By the end of the workshop, everyone mapped out an assignment to transform at least a segment of one of their courses to enhance students' curiosity, build students' ability to form connections, and empower students to create value by implementing a project/product learning experience – all based on what they'd learned in the workshop.

This workshop was also discussed in (8); this paper expands the description to incorporate the more recent updated version of the workshop activities, more survey data, and includes for the first time an analysis of course materials created as a result of the workshop.

Workshop Description and Methods

The three-day B-Fab workshop is broken into sessions devoted to its two overarching themes: skills development and pedagogy development. These two are further subdivided by topic: skills development is initiated with a "Kickoff Project", followed by "Skill Sessions" where particular Makerspace tools are taught in greater depth. The pedagogy development is sprinkled throughout and consists of theory, examples of existing STEM class projects using Makerspaces, and time for participants to develop their own class project. This is illustrated in the schedule in Figure 1.

In designing the "Skill Session" part of the workshop, instructors considered a wide variety of typical Makerspace technologies that would be useful for faculty to know. We applied an abbreviated design process to arrive at the set of CAD, 3D printing, laser cutting, soldering (and general circuitry), and Arduino. We constrained ourselves to a three-day workshop that also included time for pedagogy and course development. We also referred to what had been most popular when similar sessions had been offered as one-offs in a previous summer. We also considered what skills were felt to be teachable to a basic level in under two hours while still being useful in engineering courses. Finally, we reviewed our own Makerspace and those of peer institutions we had visited to see what technologies might reasonably be simultaneously available to a class of 25-50 students. This lead to rejection of a session with the ShopBot, the streamlining of inexpensive control / computing systems to focus on Arduino, and setting aside vinyl cutting.

	Day 1	Day 2	Day 3
8:00	Welcome & Introduction	Pedagogy 2	Rotation 5
8:30			
9:00	Kickoff		
9:30	Project (KP)	Break	
10:00		Rotation 2	Break
10:30			Coached
11:00			EML Project
11:30			Worktime & lunch
12:00	Lunch / Break	Lunch	Plus Optional
12:30	/ KP work	AcW	"Making a
13:00		Rotation 3	Makerspace"
13:30	Pedagogy 1		
14:00			Closing
14:30	Rotation 1		Reception
15:00	See group	Break	& Share-Out
15:30	schedule	Rotation 4	
16:00			
16:30	Maker Space open		
17:00	for KP		
17:30	wrap up	Break	
18:30	Group Dinner	Group Dinner	
19:30		& Discussion	
20:30			

Figure 1: Workshop schedule. Rotational "skill sessions" were: Meshmixer (CAD), 3D printing, laser cutting, soldering, and Arduino programming.

The Kickoff Project was designed to provide a platform for learning through each of the Skill Sessions and to provide an immediate sense of accomplishment to participants by giving them a fulfilling and successful maker experience on their first morning. The project used for the past two years is the building of a Bluetooth speaker, as shown in Figure 2a. Participants are given a kit with pre-laser cut and 3D printed parts, and they complete assembly (including wiring and some soldering) and testing before lunch on the first day. In the subsequent Skill Sessions (Rotations 1-5 in Figure 1), they apply the skills they learn in the further personalization of their speaker. In the Meshmixer CAD session, they draw a small element that they subsequently print in the 3D printing session and then affix to the top of their speaker. In laser cutting, they cut a design of their choosing into the top of their speaker. In the soldering and Arduino sessions, they create a LED light-show panel for their speaker and program it to blink in time with music. An example of a fully "tricked-out" speaker is shown in Figure 2b. Instructions for how to build the speaker are provided through a Instructables-type webpage (9) so participants may go at their own pace, with assistance from facilitators.

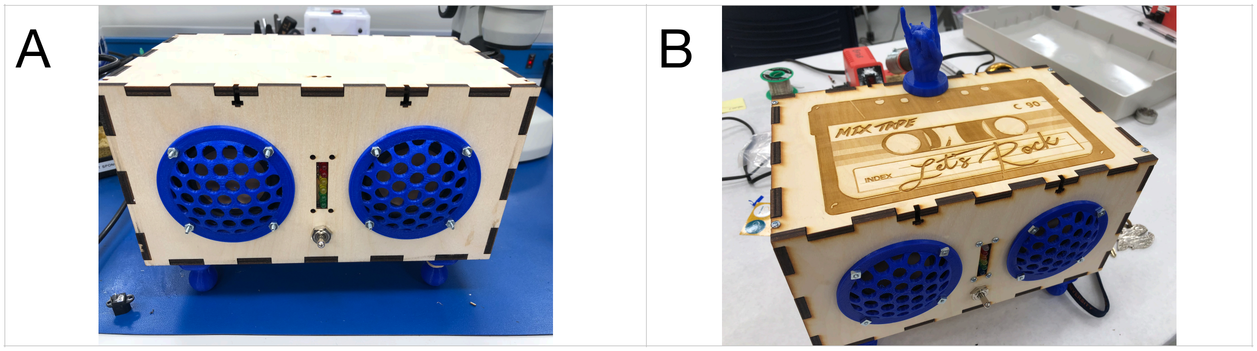

Figure 2: A Base KP speaker; B: Fully customized KP. Arduino-powered "light show" is center strip between speaker grilles.

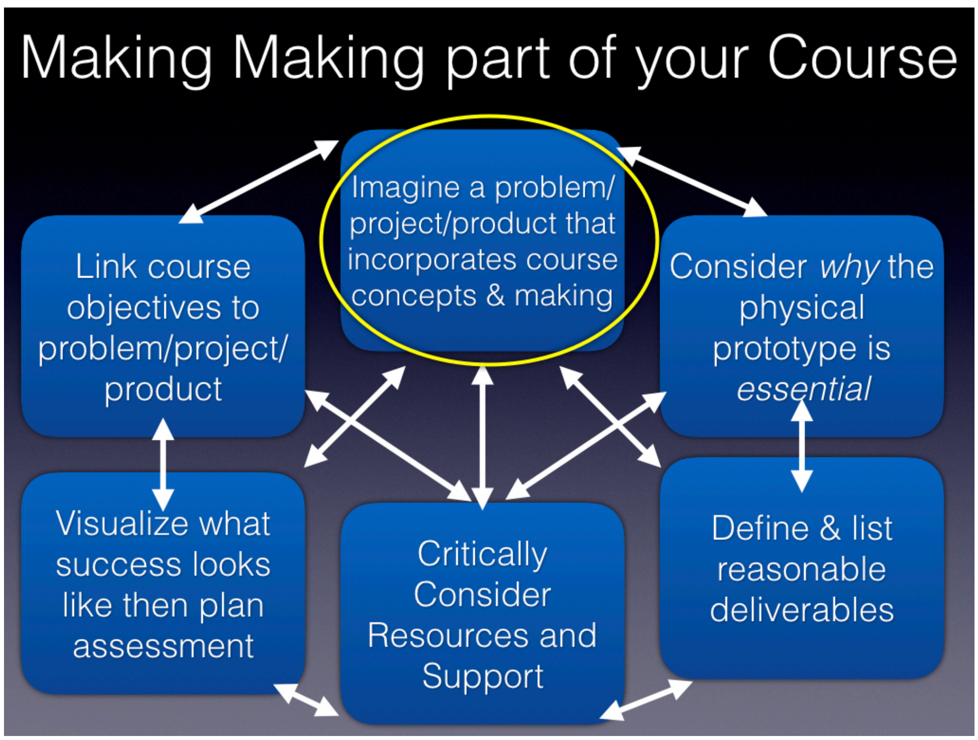

Figure 3: Framework for incorporating entrepreneurially-minded maker projects in courses; circled element is best done first, then proceed iteratively through remaining steps.

The pedagogy sessions present a framework for developing an entrepreneurially-minded PBL experience for students in a makerspace, shown in overview in Figure 3. Faculty are given background on Bloom's taxonomy (10) and the importance of active learning, followed by developmental support in selecting course objectives that might be appropriate to emphasize in a n EML maker project. Practical insights about using maker-technologies in classes are also shared, such as making sure to leave enough time for 3D printing. Finally, faculty are presented with a series of examples, mostly captured in the form of "KEEN Cards" (11), of existing class projects. Throughout this time, faculty are given time and coaching support as they develop their own class project / student experience. On the last day, there is open time for participants to put the finishing touches on their class project and then share it with all participants and facilitators for feedback and discussion. Participants are then empowered to employ these techniques in classes, assigning authentic problems and projects to their students resulting in greater student engagement, curiosity, and learning.

Another key element of the pedagogy section is that facilitators work one-on-one with participants to anticipate and pre-troubleshoot possible issues with their proposed class projects. This is a valuable but difficult to summarize part of the workshop, as the coaching that happens is very specific to each participant and project. Each facilitator has significant experience with maker projects and research-based instructional strategies, and brings this to bear to help participants have the best shot at a successful project plan. It is also part of the pedagogy sessions that participants should plan to implement their new project at least three times before it's at its peak of efficacy.

The goals for participants following completion of the B-FAB program are that they will:
1. Have drafted an activity or project for a class they teach that leverages some of the skills learned in the program for EML.
2. Understand how the capabilities of Maker Space equipment can support EML, including the strengths and limitations of the equipment. Each participant will be trained on at least two pieces of MakerSpace equipment so they can utilize that equipment in EML.
3. Be aware of the software needed to effectively use MakerSpace equipment, and have used at least two different freely available software packages used for rapid prototyping.
4. See concrete examples of how MakerSpace equipment has been used in transformative EML student experiences in the curriculum.

Methods

Two approaches were applied to assess the outcomes of the workshop. First, a brief customer-satisfaction-type survey was given to all participants at the end of the workshop for immediate feedback.

Results are based on survey and artifact from three years worth of participants (n=50) in the B-Fab workshop. About half of all participants are faculty or staff from Bucknell University. The balance are faculty and staff from other KEEN schools. Faculty participants represent a wide variety of STEM fields, while staff participants represent teaching and learning centers, student life, and STEM technical support.

KEEN Cards are faculty-created items an online repository of class activities, course projects, courses, and curricula designed to support entrepreneurially-minded learning (11). Participants were encouraged to capture their new class activity in the form of a Card by the end of the workshop. Omitting participants who had only partial participation (ex: leaving early due to illness or travel) and counting repeat attendees only once, 45 total faculty remain in the sample set. Cards, when present, were analyzed in the following four ways. First, cards were sought for each full participant, and their presence or absence was noted. Second, the presence of outcomes related to the physical creation of a prototype were tallied. Finally, the text description of the class activity was read for activities related to making and then grouped according to emergent themes. For comparison,10 randomly selected "Exemplar" Cards by faculty who have not attended these workshops were subject to the same analysis. Exemplar cards are a subset of those published on the website judged by website curators to be of exceptionally high quality in terms of writing, pedagogy, and expression of entrepreneurial-mindset and representing a wide variety of disciplines, projects, and approaches. These were selected randomly from the entire collection of Cards with the Exemplar designation. These cards were selected as controls to give a picture of what a "typical" well-written pedagogical EML intervention might include, allowing us to see differences that a workshop that focuses specifically on Makerspace EML pedagogy might create in the class environment.

Results and Discussion

Of the 45 faculty who have attended the full duration of the workshop at least once, 30 created 29 unique Cards based on their B-Fab project. It is worth noting two observations about these Cards, which are semi-public publications of class content available to any educator who registers with the EngineeringUnleashed website. First, that the 2019 workshop used Cards as the platform for developing and sharing participant's final projects from B-Fab, so in that case all participants had at least a draft Card by the end of the workshop. At the end of the workshop, a number of participants chose not to publish their Card until they had done additional work; the count above represents only those Cards that are published as of February 1, 2020. For the 2017 and 2018 workshops, participants were encouraged to publish their work in Cards, but shared their draft activities by the end of the workshop in other ways. Therefore, for 2017 and 2018 participants, Card publication represents an above-and-beyond step to go back and share what has been implemented and likely underrepresent actual class impact. In either case, the publishing of a Card suggests a level of commitment to implementing the proposed activity.

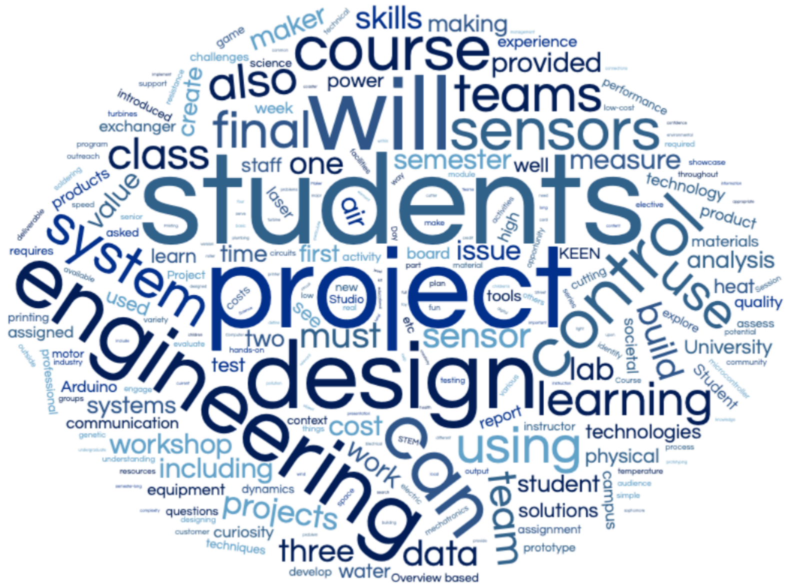

Figure 4: Word cloud from Cards describing B-Fab projects.

Figure 5: Word cloud of project descriptions from 10 Exemplar Cards

Of the 29 published Cards, 79% include “create a model or a prototype” as a student outcome. By contrast, the comparison group of Exemplar Cards have this outcome only 30% of the time. This is consistent with our expectation that the workshop is helping inspire student projects that use some of the Maker Space's prototyping tools and also demonstrate greater faculty comfort in assigning such projects.

To gain a rapid overview of concepts within Card descriptions, word clouds were generated. Figure 3 shows the cloud for the 29 B-Fab Cards, while Figure 4 shows that for the Exemplar Cards. Many common terms are important to both groups of Cards, such as students, course, project, and design. Standout elements from the B-Fab related cards are the increase use of the words engineering, project, control, system, sensor, and team relative to the Exemplar cards, suggesting potential construction of more sophisticated systems as part of these courses, relative to what might otherwise be happening in class.

Reading the descriptions bears this out, where faculty describe their projects in terms of physical creation ("..build their own projects," "Students…are frequently evaluating and tinkering with their prototype," "build a scale model"). In addition, the maker-projects are often described in terms of added practical benefit ("students can observe that it requires venting for things to drain,") and student motivation ("Students find it more engaging and memorable to solve a real problem.") Phrases like this suggest that faculty believe student learning and engagement will be positively affected by inclusion of their B-Fab project in classes.

Facilitators assessed the attainment of Skills Session and Kickoff Project goals during the workshop, and reported that all participants were able to meet the basic goals of each session, as well as emerge with a functional speaker by the end of the workshop. Facilitators also reflected on participants' plans after the one-on-one coaching during participant's work time. Facilitators felt in general that their greatest contributions during this segment were first to connect participants with existing Cards or ASEE papers or similar resources that showed projects that would be similar to or helpful for the participant's proposed project. Facilitators also helped participants think through resources and timing for their proposed projects - how many days and 3-D printers are needed to move the entire first-year class through a simple printing exercise, for example. It is the facilitator's informal observation that the most common failure mode for maker class projects is resource constraint - students' not having enough time or equipment or support to complete the project. The pedagogy segments of the workshop are designed to help mitigate this issue, and slides and handouts are available from the corresponding author upon request.

The participants were surveyed on their experiences with B-Fab. They gave specific feedback on the various Skills Sessions, as well as addressing the value of the workshop as a whole. In response to the question "How are you thinking of using what you learned" participants responded by describing class projects, outreach activities and "a renewed commitment to incorporate as much hands-on as possible." When asked what they wished the workshop would include in the future, the majority said it was fine as-is, but constructive feedback on choice of CAD software and ease of manipulation for soldering was also offered. In the 2018 offering, the pedagogy sessions were seen as long and less helpful than they had been in the 2017 offering, leading to a reconfiguration to shorter, more pointed, mid-day pedagogy sessions leading faculty in 2019 to agree or strongly agree that all sessions, including pedagogy, were helpful. Out of 28 survey respondents, 89% agree that “B-Fab was worth my time”, while 7% “agree somewhat” and 3% were neutral on the value of the workshop.

Conclusions and Next Steps

B-Fab is effective at introducing Maker Space technologies to faculty and staff who then subsequently use those skills to create innovative hands-on assignments and experiences for students. The workshop team plans to deliver B-Fab again in the future, and would like to expand to a “B-Fab 2” that allows participants to go more in-depth on maker technologies, explore some additional maker-technologies like the ShopBot, and troubleshoot student projects in progress. Further, as it often takes multiple academic years for a project to be optimally effective, we would like to return to past participants and encourage them to update their Cards to reflect their project in its final form.

Acknowledgement

B-Fab workshops from 2017-2019 were offered with support from the Kern Entrepreneurial Engineering Network (KEEN).

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