BFab for Faculty: Using Making to Empower Entrepreneurially-Minded Learning

Margot Vigeant
Chemical Engineering
Bucknell University
Lewisburg, PA
mvigeant@bucknell.edu

Donna Ebenstein, Eric Kennedy
Biomedical Engineering
Bucknell University
Lewisburg, PA
de009@, eak012@bucknell.edu

Wade Hutchison
Library & IT
Bucknell University
Lewisburg, PA
whutchis@bucknell.edu

R. Alan Cheville, Matthew Lamparter, Michael S. Thompson
Electrical and Computer Engineering
Bucknell University
Lewisburg, PA
rac039@, mlampart@, mst008@bucknell.edu

Joe Meiser
Art and Art History
Bucknell University
Lewisburg, PA
joemeiser@gmail.com

Nate Siegel
Mechanical Engineering
Bucknell University
Lewisburg, PA
nps004@bucknell.edu

***Abstract*—Work in progress (innovative practice). Availability of campus maker-spaces has grown significantly over the past decade. While students make use of these tools for their own curiosity, research, and senior design courses, the potential for use of these spaces across the engineering curriculum goes unrealized. With tools such as laser-cutters and 3-D printers readily available to students, faculty need no longer wait for senior design to ask students to physically realize a design that's relevant to a class topic. Our hypothesis was that the primary barrier preventing faculty from assigning in-depth prototype-based class projects was their own unfamiliarity with the tools the students would need to use to create those prototypes. We created a summer workshop on the fabrication capabilities of our maker-spaces and entrepreneurially-minded learning (EML) and delivered it to over 30 faculty and staff in the summer of 2017. Our workshop aimed to increase faculty familiarity with these tools and with the pedagogical approaches that leverage them and thereby empower faculty to assign open-ended, prototype-based experiences that center value-creation. Faculty were further coached on inductive pedagogical approaches such as problem-based learning. The subset of faculty that attended at least three different topical workshops and the pedagogy workshop went on to develop and share new assignments for their courses. This paper describes the workshop content and structure, results of the post-workshop survey, and an overview of the student assignments generated in the workshop. Results to date suggest that faculty did create assignments reaching higher levels within Bloom's taxonomy as a result of the workshop and more fully implement the "value-creation" aspect of EML**

Keywords— Entrepreneurship, making, faculty development

This work was funded by a grant from KEEN.

I. Introduction

Engineering graduates, whether they will be starting their own businesses, promoting their ideas within corporations, or advocating for their work within research laboratories, benefit from skills in innovation, design, and prototyping. KEEN (Kern Entrepreneurial Engineering Network) identifies "curiosity, connections, and value creation" (the 3 Cs) as the primary tenets of the entrepreneurial mindset (EM) and classes that engage these habits of mind as entrepreneurially-minded learning (EML) [1]. It is this definition we apply throughout this work, focusing on creating assignments that should foster these "3Cs." KEEN is not the only entity interested in such outcomes, however. The National Science Board cites early exposure to engineering and informal access to STEM activities as key in fostering the next generation of innovators [2], while the National Academy of Engineering, in the *Engineer of 2020*, notes hands-on design-based courses as important for the future of engineering [3]. The Global State of the Art in Engineering Education [4] builds on these earlier works and cites programs with entrepreneurship and active-problem-based learning as characteristic of current leaders, while future leaders also bring socially-relevant design projects to their students. Access to and familiarity with rapid prototyping tools can allow students to physically realize designs when tackling these projects, rather than just completing the design process on paper. Physical prototypes aren't just "neat"- they also facilitate explanation of designs, and allow testing of designs to see if they meet target specifications. The *ASME Vision 2030* study suggests that students could be better prepared for professional practice through additional design-based, hands-on experiences and that faculty skills should grow to include experience with innovation and product realization [5].

978-1-5386-1174-6/18/$31.00 ©2018 IEEE

Assigning real-world open-ended problems enhances student engagement [6] whether or not these problems require a prototype. However, problems that do contain a prototype may enhance students' curiosity and motivation more than those that do not [7]. Both elective and required coursework has sought to bring concepts and skills in innovation and entrepreneurship to engineering students [8].

Students who identify as "makers" benefit from this identity, and also create a more positive atmosphere within STEM education more broadly, and their pathway to a maker identity is significantly supported by adult mentorship [9]. Making is often perceived as homogeneous [10], and a positive step towards its broadening is building comfort within makerspaces, and by extension, in EML through coursework. It is believed this approach can work in the other direction as well and that the many pathways makers follow can be used to broaden access to engineering as a whole [11].

As stated above, there is a wealth of reasons to give students access to makerspaces for their own benefit and for the benefit of their coursework [2-11]. Our campus, like many, has several makerspaces available for student, faculty, and staff use. We observed, however, that many of our faculty colleagues were reluctant to assign complex real-world problems where students were expected to use the makerspace. There are many potential reasons for this reluctance, foremost of which was many faculty did not feel that they were sufficiently familiar with the makerspace technologies or relevant pedagogy to successfully assign such projects.

The primary goal of the BFab for Faculty workshop, BFabF, was to provide faculty and staff with basic instruction in various fabrication techniques available in the makerspaces on campus through skills-building projects. Skill building projects within the workshop aimed to expose participants to a broad range of readily accessible fabrication tools with a low barrier to entry: 3-D printing, laser cutting, soldering, and use of Arduino microcontrollers, along with associated software. In addition, participants were shown examples of successful existing EML pedagogy and projects utilizing makerspace equipment, and time was allocated for the development of individual class activities or projects that could be disseminated to the broader community. Sessions sought to empower participants to employ these techniques in classes, assigning authentic problems and projects to their students. Ultimately, the planned long-term outcome of this project is to observe greater student engagement, curiosity, and learning in courses taught by faculty participants.

It is our hope that the skills and projects included in BFabF will motivate participants to integrate rapid fabrication technologies into some aspect of their teaching or research, thereby impacting students and building a community that's inspired to learn more, build more, and disseminate more...to become lifelong Makers..

II. Methods

The main "method" employed was to offer two levels of participation ("full" and "drop-in") in a workshop, described in sections A and B below, complemented by data collection to understand the impact of the workshop, described in section C.

A. Workshop Description

The BFabF workshop was based upon an earlier student-focused workshop, BFab, 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. For faculty, a new curriculum was developed based on the authors' experiences with the student workshop, EML, and faculty development. Following completion of the BFabF program, it was expected that participants would:

1. Be aware of the capabilities of the makerspace equipment, including both strengths and limitations, and be trained users on at least two pieces of makerspace equipment.
2. Be aware of the software needed to effectively use the makerspace equipment, and have used at least one of the freely available software packages used for rapid prototyping.
3. Have seen examples of how makerspace equipment has been utilized in transformative student experiences in the curriculum.
4. Have drafted an activity or project for a class they teach that leverages some of the skills learned in the workshop to create an engaging, higher-order learning opportunity.

In order to work more effectively as "adult education", the one-week intensive workshop model was dropped in favor of a summer-long flexible model, shown in Fig 1. Seven topics were offered as half-day workshops, at least three times each. Six of these were technical skills-sessions, while the last was a session on pedagogy. These were complemented by overview sessions at the start of the summer and a showcase session in August.

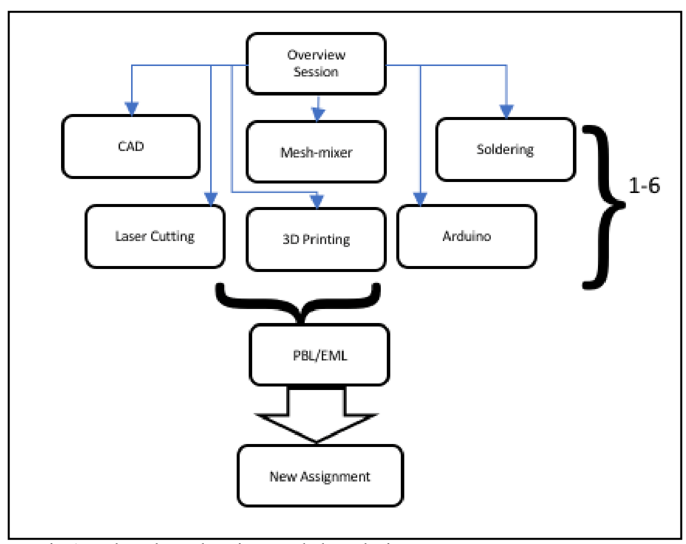

Fig 1. Flowchart showing workshop design

We targeted ten "full" participants for our pilot year and offered each a small honorarium with the expectation that each would a) attend the overview session, b) attend at least three technical skills-sessions (described below), c) attend the pedagogy session, and d) create and share a class activity/project/assignment based upon what they'd learned. The sharing was expected both at the showcase in August and in an online database accessible to other faculty. All participants in this group were drawn from the College of Engineering. There were a small number of open seats in each sessions that were marked as "drop-in" and were open to other faculty and staff on campus.

Most participants were recruited through the college of engineering's email listserv. We also used targeted email to individuals and groups who had expressed interest in the makerspace or whose academic area seemed likely to benefit from inclusion of more hands-on projects.

B. Workshop Elements

In designing the BFabF workshop, workshop leaders chose a sub-set of possible makerspace technologies as the focus. These particular fabrication technologies were selected because they were all a) available at multiple locations on campus, b) safe to use by novices after only 2-3 hours of training, c) able to produce something meaningful when used by novices after only 2-3 hours of training, and d) felt to be foundational for rapid prototyping. Because both 3-D printing and laser cutting rely upon having good CAD drawings, two approaches to CAD were also included. SolidWorks was chosen as the basic CAD software as it is widely available on our campus, while MeshMixer was selected for manipulating existing CAD files and creating more artistic designs as it is freely available for academic use.

Skills and pedagogy sessions were taught with the goal that a faculty member from any discipline might apply what they learned in any course. The focus of the new assignment development in BFabF was on lower-level courses where such work is typically absent. The workshop sessions were also developed as independent units, so they could be completed in any order. The workshop descriptions provided to faculty were:

a) Designing 3-D printable forms with Meshmixer

You will learn to use the program Meshmixer to create 3-D printable objects. Meshmixer is an easy to use program that's great for beginners and since it's free you can install it on your computer for future projects. By the end of the session participants will be able to use Meshmixer to modify downloaded 3-D forms and create unique 3-D printable objects. *This session is recommended before the 3-D printing session.*

b) SolidWorks for beginners - CAD basics for laser cutting & 3-D printing (a minute to learn, a lifetime to master)

SolidWorks is one of the most widely used 3-D computer aided design programs in industry. It's also a basic starting block for other tools like 3-D printing, laser cutting, etc. You will learn how to navigate the SolidWorks software and use SolidWorks to create objects that can be exported for 3-D printing, laser cutting, or manipulation in Meshmixer. Solidworks is free on campus so you can install in on your work computer for future projects. *If you are unfamiliar with CAD, please take this session before laser cutting. Take this session or the Meshmixer session before a 3-D printing session.*

c) Introduction to 3-D Printing

3-D printers are versatile machines that can be used to produce three dimensional prototypes of nearly any shape. In this workshop you will learn how to format a file for printing, set up a 3-D printer, and successfully complete a print. You'll also learn how to diagnose and address some of the problems commonly experienced when printing. All participants will be able to set up a 3-D printer, including changing filament and leveling the bed, and successfully execute a print. *If you are unfamiliar with CAD, please take either the "Meshmixer" or "Solidworks" session before this one.*

d) Laser-Mania

Laser cutters can be used to quickly and accurately cut or engrave many materials made from wood or plastic. In this workshop you will learn the basics of laser cutting including how to operate a laser cutter, how to design for laser cutting, how to cut parts from sheet stock, and how to join laser cut pieces together to create assemblies. All participants will be able to operate a laser cutter to both cut parts out of sheet stock and to engrave images in wood or plastic. *This session is recommended for those familiar with CAD or who have taken the "SolidWorks" session first.*

e) Circuit Basics with Through-hole and surface mount soldering

This session will provide you with the skills necessary to solder through hole and surface mount device packages, as well as examine the reasons you might choose one mounting type over the other. Participants will be able to solder both on-surface and through-mounted components, and be able to talk about basic circuit design and why you would choose one approach over another.

f) Making a sensor system with Arduino

Microcontrollers are small, often inexpensive, programmable computers that you can use to make interactive devices, clothing, or measurement equipment. In this session, we'll use one popular microcontroller, the Arduino, to make an interactive coffee-cup. After this session, participants should be able to create a simple program and run it on an Arduino, should be aware of the capabilities of devices like Arduino boards, and have some ideas for how they might creatively use such devices in the future. *This session is best done after the soldering and circuit basics session.*

g) Using EML and PBL in the classroom

This workshop session will introduce the entrepreneurial mindset, entrepreneurially-minded learning, and the three most common forms of "PBL" - Problem, Project, and Product - Based Learning. Then we will workshop with participants on their own ideas for how to leverage what they've learned for a course of their choosing. This session is required for all "full" participants, all are welcome.

This work was supported by a grant from KEEN

C. *Study Methods*

In order to assess the effectiveness of the workshop at attaining its goals, (described in section A and B), a mixed-methods approach was used. Workshop leaders assessed each participant on their attainment of each skill sessions' educational outcome during that skill session, using their own observation and professional judgement. It should be noted that the outcomes were modest; typically at the level of "aware of…." or "beginning," all within reasonable reach of a three-hour workshop. All participants were also given an anonymous survey about their experiences in the workshop after the workshop's conclusion. This was primarily a Likert-scale survey asking questions such as "I met the goals for (skill session x)" and "I plan to use what I learned in class/research/service." The final study approach involves analysis of the assignments generated by workshop participants. This is described in more depth in Future Work.

III. Results

BFabF was more popular than expected. Twelve faculty applied to be "full" participants and all were admitted (above the expected 10); these faculty represented departments from across the College of Engineering. An additional 28 "drop-in" faculty and staff participants attended at least one workshop session. Workshop leaders were asked to assess if participants reached the target levels of achievement with their topic, and all reported that outcomes were met for 100% of participants.

All participants were surveyed after the end of all workshops. The single biggest formative request in the survey was for "more time;" in the future this will be accommodated by adding pre-reading / pre-workshop homework so that all of each skills session can be spent on doing instead of being split between description and action. 96% of respondents agreed that "Overall, I feel my participation in BFab for faculty and staff" was worth the time, a very positive outcome.

IV. Discussion

Our overall guiding hypothesis was that faculty unfamiliarity with maker technologies is a significant factor in preventing faculty from assigning open-ended real-world problems in which students would use the makerspace. This work was not intended to demonstrate or refute this hypothesis universally, but rather to more humbly observe if a hands-on faculty workshop could address this discomfort and result in more of these engaging assignments. While we cannot establish a causal link, assignments created by faculty participants demonstrate they are more willing to engage in complex hands-on assignments after the workshop.

Of the 12 "full" participants, two proposed very ambitious novel assignments that required additional development and will be piloted in the coming academic year. Nine faculty created and assigned their novel projects and assignments in a wide variety of courses. Analysis of these assignments is ongoing, but preliminary observations include that a variety of educational objectives were achieved through prototyping, including metacognition about course material, experience with the distinction between theory and practice, and the expected development of new products.

For example, two courses (a first-year seminar and an upper-level engineering elective) incorporated significant projects where students were asked to create a personal expression of what they had learned through the course experience. For the engineering elective, students created educational collaborative board games that captured the multi-faceted aspects of using genetic engineering in production of food or medicine. In two other courses, students were asked to create prototypes of novel projects based upon what students had learned about in class; for example, a composites-based product for an advanced materials course. One course, in biomedical imaging, had students create physical models of real medical scans as a demonstration both of how valuable and how challenging this seemingly straightforward action is. Finally, a statistics course used 3-D printing to create a range of theoretically "identical" items in order to develop a more accurate sense of specifications, tolerances, and variability in manufacturing and how this is communicated statistically.

V. Future Work

Ultimately, we would like to know the impact on students resulting from this workshop. Our planned analysis approach contains both quantitative and qualitative elements which will focus on the syllabi and novel assignments generated by full workshop participants. We will compare syllabi from before and after the introduction of the new assignment, enumerate additional course outcomes, and evaluate the revised Bloom-level [12] of all outcomes both on old and new syllabi. Our hypothesis is that the inclusion of PBL/EML prototyping-based assignments will allow courses to reach higher levels within their course outcomes than they did prior to the inclusion of these assignments. We will apply this same approach to the specific outcomes detailed in the assignment itself. Finally, we expect to develop a typology of prototypes considering how they are used in assignments. Review of the few assignments summarized here suggest they go beyond the "demo version of new device" that most people expect.

In our first offering of BFabF participants were recruited from our own campus. Subsequent offerings will include participants from other universities who will travel to our campus. We have restructured BFabF to be completed in three full days, making the program more convenient for travelers. The content will remain essentially unchanged, with training sessions taking place in parallel to better utilize available time and resources. In addition, participants will be asked to complete "homework" prior to the start of the course, and also given the choice to opt out of training that they already have (e.g. CAD).

Finally, the novel assignments created by full participant faculty are being shared through www.engineeringunleased.org where these engaging assignments can serve as seeds for other faculty to create similar assignments for their own courses.

REFERENCES

[1] KEEN, Kern Entrepreneurial Engineering Network. "Entrepreneurial Mindset Framework." *KEEN'Zine*, 2015. Accessed at: https://engineeringunleashed.com/resources/keenzine.aspx

[2] *National Science Board, Preparing the Next Generation of Stem Innovators. Washington, D.C.: National Science Foundation, 2010.*

[3] Committee on the Engineer of 2020, *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*. Washington, D.C.: National Academies Press, 2005.

[4] R. Graham, "The global state of the art in engineering education," Cambridge, MA: New engineering education transformation MIT, 2018.

[5] ASME Board on Education, "Vision 2030: Creating the future of mechanical engineering education," Washington, D.C.: ASME, 2012..

[6] K. A. Smith, S. D. Sheppard, D. W. Johnson and R. T. Johnson, "Pedagogies of engagement: Classroom-based practices," *Journal of Engineering Education*, vol. 94, no. 1, pp. 87-101, 2005

[7] C. Kim *et al.*, "Assessing situational curiosity and motivation in open-ended desgin electives," *Frontiers in Education*, 2015

[8] S. R. Brunhaver, M. Lande, S. D. Sheppard and J. Edward Carryer, "Fostering an enterprising learning ecology for engineers," *International Journal of Engineering Education*, vol. 28, no. 2, pp. 355, 2012

[9] S. Weiner, M. Lande and S. Jordan, "Making identities: Understanding the factors that lead young adults to identify with the maker movement," *American Society for Engineering Education*, 2017

[10] G. N. Svarovsky, M. B. Bequette and L. Causey, "Making connections: Challenging the perceived homogeneity of making," *American Society for Engineering Education*, 2017

[11] C. Foster, A. Wigner, M. Lande and S. S. Jordan, "Learning from the parallel pathways of makers to broaden pathways to engineering," *International Journal of STEM Education*, vol. 5, no. 1, 2018

[12] D. R. Krathwohl, "A revision of bloom's taxonomy: An overview," *Theory into practice*, vol. 41, no. 4, pp. 212-218, 2010