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Promoting active learning in an engineering library

Jean L Bossart (Engineering Librarian)

Engineer/Engineering Librarian

Sara Gonzalez

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Jean L. Bossart, PE and Sara Russell Gonzalez, PhD
University of Florida

Abstract

Active learning engages students to experimentally participate in the learning process, promoting a deeper understanding through application of knowledge. Examples of active learning in engineering education include group design projects, hands-on building activities, and experimentation. Like many college and university libraries with makerspaces, the University of Florida Libraries operates a 3D printing service as part of their makerspace. The service provides low-cost 3D printing to students and faculty. After several years of offering a staff-managed service, we realized that although the 3D service had met the initial goal of providing access to affordable 3D printing, students still lacked hands-on experience with 3D technology. In an effort to promote active learning, the engineering library began circulating portable 3D printers for individual use. The first 3D printers available for check out were Printrbot Plays, partnered with a wheeled Pelican case and 250 grams of filament. A LibGuide provided instructional materials. These circulating printers empowered students to explore 3D printing and troubleshooting outside the library, in their own space and timeframe. Taking student engagement to the next level, the librarians also developed and taught a 1-credit honors course where students worked in groups to build 3D printers. The course facilitated a deeper understanding of 3D technology through assembling 3D printers from kits, thereby teaching students the basic mechanics of 3D technology and use of tools. The course had a small cohort of twelve students, split into four teams of three, who built iMade3D Jellybox kits in a weekly class held within the engineering library. Student feedback was highly favorable for both hands-on learning methods. This paper discusses the benefits and challenges of offering these active learning opportunities in an engineering library.

Introduction

The University of Florida (UF) science and engineering library, like many modern libraries, offers 3D printing services where students may submit 3D models for library staff to print. This 3D printing service was started at the UF libraries in April 2014 with two locations and three printers total. Over the years, the service expanded to three locations and twelve 3D printers and has now operated continuously for about eight years. Patrons submit print requests either in person or on-line and the library staff prints their models for the patron to pick-up once the print is completed.

UF has sixteen colleges and patrons from almost every college use the library 3D printing services. Figure 1 shows the distribution of print jobs by UF colleges. As expected, patrons from engineering departments are the heaviest users of library 3D printing services, with 59% of the patrons identifying their college as engineering.

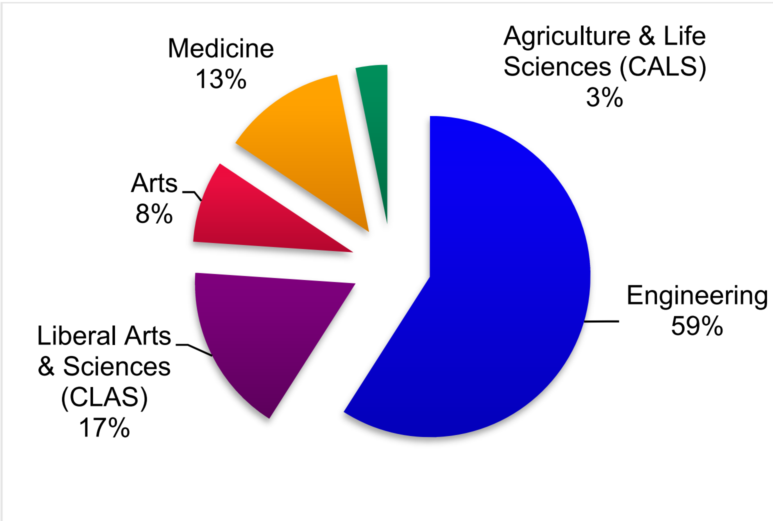

Figure 1. Distribution of print jobs by college.

The libraries average about 70 print orders per month and the average printing time is about 4 hours and 17 minutes per print job. Figure 2 shows that undergraduates are the largest users of the 3D services, followed by graduate students, and staff. Approximately 3% of users are from the local community.

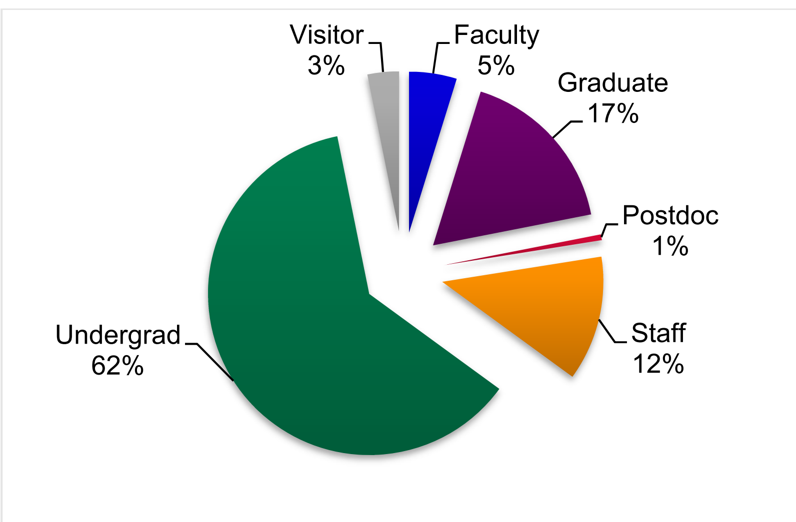

Figure 2. 3D service users.

Despite the diversity of student users of the libraries' 3D printing facilities, the service provided little to no active learning opportunities. Students expressed a desire for a more hands-on opportunity to learn and use the technology. Accordingly, the science and engineering library sought to explore ways to involve students more actively with the 3D technology in particular and with operating and troubleshooting mechanical equipment in general. This paper details the evolution of the UF science and engineering library 3D service, starting from staff-mediated production to enabling self-printing and finally to hands-on experience for the students to build and troubleshoot 3D printers thus gaining a deeper understanding of the technology through active learning.

Literature review

Libraries reportedly began joining the maker movement in 2006 when the first Maker Faire was held in San Mateo, California [1]. Shortly after, academic and public libraries joined the maker movement offering 3D services to their patrons [2, 3], with 3D printing in university research libraries becoming a popular trend in the early 2010s [4, 5]. Expanding 3D printing facilities into academic libraries, instead of simply housing them in engineering department laboratories, also helped facilitate access to students of many majors, not just engineering [6].

As academic libraries developed and expanded their 3D related services to include such amenities as 3D scanning and educational resources to enhance learning experiences [7, 8], the more formal concept now known as the *Makerspace* took hold [9]. Case studies at public and academic libraries have demonstrated the relevance of makerspaces and the highly utilized library service they provide [10, 11]. Initially, makerspaces were tucked into a corner of the library but as their popularity grew, so did the need for expanded space to accommodate the added equipment and services. The continued expansion of makerspaces has also generated consideration for their planning [12].

Getting students interested in STEM can be a challenge and academic libraries look for ways to engage their students. 3D printing has been used as an active learning experience for diverse groups of students [13]. By offering library workshops on 3D printing, academic libraries expand the 3D community beyond engineering students [14]. Teaching 3D modeling is another example of an expanded educational experience which some academic libraries have added [15].

The concept of active learning is most often described as an instructional or learning approach [16] and active learning has been shown to increase knowledge in the STEM disciplines and empowers students in the learning process [17]. It supports the development of engineering competencies required in the workplace, such as teamwork, problem solving and analysis; as well as enhancing a student's employability with companies recruiting new hires who have 3D printing experience. The literature shows that students' performance and retention rates are improved when implementing active learning [18].

At the University of Toronto, their library offered students the option of walk-up do-it-yourself 3D printing after taking a training workshop [19]. For students to gain hands on experience, the Munich University of Applied Sciences offers a one-day workshop where students learn 3D printing and gain hands-on experience operating and troubleshooting 3D printers. Working in teams of three, using eight small 3D printers, the 24 students collaborate to solve challenges [20]. Other colleges and universities have begun offering credit course in 3D printing [21]; however, the literature provides few if any examples of active learning where university libraries offer 3D printers for check-out with instructional materials or offer a hands-on class where students build a 3D printer.

Objective

Active learning can increase student engagement and help prepare engineering students for the workforce. The objective of the expanded 3D services at the UF science and engineering library was to provide students with hands-on experiences. Through this active learning environment, the goals were to provide students opportunities to:

- Increase confidence in their mechanical skills
- Learn how to use hand tools
- Troubleshoot and make minor repairs
- Practice following detailed technical instructions

While many libraries provide 3D printing services, UF was one of the first to provide portable 3D printers for check-out and one of the first to offer a class where students build a 3D printer.

Methodology and Results

To provide students with an active learning experience with 3D technology and tools, the UF science and engineering library added circulating 3D printers for students to check out of the library and learn how to print their own models. Taking the engagement one more level, the library also developed a credit course for students to deepen their understanding of 3D technology through building 3D printer kits, thereby teaching them the basic mechanics of the components, as well as typical troubleshooting and repair strategies. The following sections describe each of these active learning experiences.

Circulating 3D Printers

The UF science and engineering library purchased 22 portable 3D Printrbot Play printers for students to check-out for a period of three days. The portable 3D printers were acquired to provide students with the hands-on experience of producing 3D prints, including using the processing software and directly operating the printers. The library developed a LibGuide along with a video tutorial with full instructions for operating the printers.

Over a 12-month period, the 22 circulating 3D printers were checked out 272 times. Not all of the portable printers were in circulation at one time. Some of the printers were being repaired while others were on long term check-out to faculty. These Printrbot Plays are metal printers with a build volume of 4x4x5 inches and weight of 16 pounds. The printers were checked out with a 250-gram roll of white polylactic acid (PLA) filament and a wheeled Pelican carrying case for easy transport. At check-out, a link to the LibGuide was provided with video tutorials, links to download the free 3D printing Cura software, and the printer profile.

The students benefited from the educational opportunity of learning to 3D print small objects. The learning outcomes included how to follow detailed instructions, prepare models and use the Cura software, operate the 3D printers, and troubleshooting. Students were provided instructions on how to troubleshoot and make minor repairs. The UF science and engineering library has an extensive Tool Library where students could borrow tools to make minor repairs. The tools available include digital calipers, precision screwdrivers, socket sets, Dremel™ rotary tools, and soldering kits.

To assess the usage and impact of the 3D printer lending service, the survey shown in Figure 3 was distributed to students with the 3D printers. Students were asked 8 questions about themselves and their experience with checking out the 3D printers. An Institutional Review Board (IRB) review of the survey entitled Investigation of Usage of Portable 3D Printers, IRB # 201801653 was completed. Participation in the survey was optional and responses were anonymous.

You are being asked to participate in a research study about your experience checking out a 3D printer in [University] Science Library. The purpose of the study is to help us improve the library's 3D service. The study will take approximately 5 minutes to complete, participation is optional, and all responses are anonymous. There are no risks for participating in the study.

1. What is your status?

Circle:	Undergraduate	Graduate	Staff	Faculty		

2. What is your major or department?

3. What is your level of expertise with 3D printing?

Circle:	Beginner	Intermediate	Expert			

4. How many times have you checked out a printer from [Library]?

Circle:	1st time!	2-3	4-5	6+		

5. What is the purpose of your print?

Circle:	Class project	Personal Use	Product Development	Research	Other	

6. How did you find out about the library's 3D printers?

Circle:	In a class	Word of mouth	Social Media or Newspaper	Saw in the library	Other	

7. Why did you check out a printer (instead of submitting it to the library's 3D service or elsewhere)?

Circle:	Because it was free	I wanted to learn how to 3D print.	Needed fast turnaround	I didn't know of any other options	My professor required or recommended that I check out a printer.	Other

8. Is there anything else you want to share with us anonymously?

Figure 3. 3D printer lending service survey.

Fifteen students responded to the survey: 11 undergrads and 4 graduate students. As shown in Figure 4, more than half of the 15 students were engineering majors, 2 students were health science majors, 2 were other science majors, and 3 students did not respond to this question. When students were asked to self-define their level of experience using 3D printers, 7 said they were beginners, 7 said they were intermediate level, and 1 said they were an expert. For 9 of 15 students, this was the first time they had ever checked out a 3D printer. Three students had checked out the printer more than 6 times.

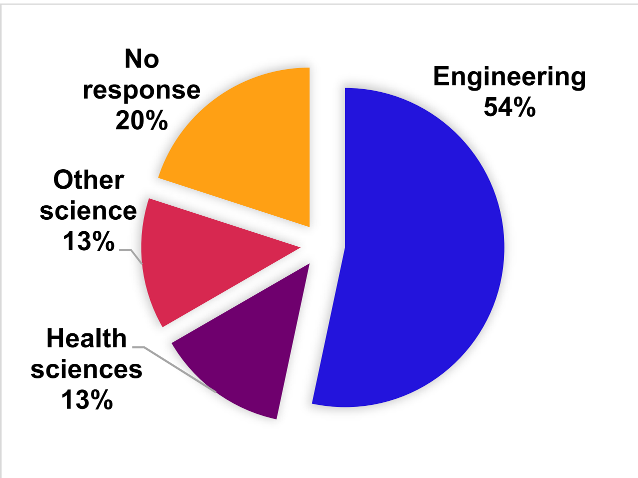

Figure 4. Majors of the student survey respondents.

As shown in Figure 5, personal use was the most common reason for checking-out a 3D printer. Five students said they checked out the printer for research purposes and one student said they were doing product development. Seven students said they checked out a printer because they wanted to learn how to 3D print while four students needed fast turnaround and thought it would be quicker to print it themselves rather than waiting in the 3D print service queue.

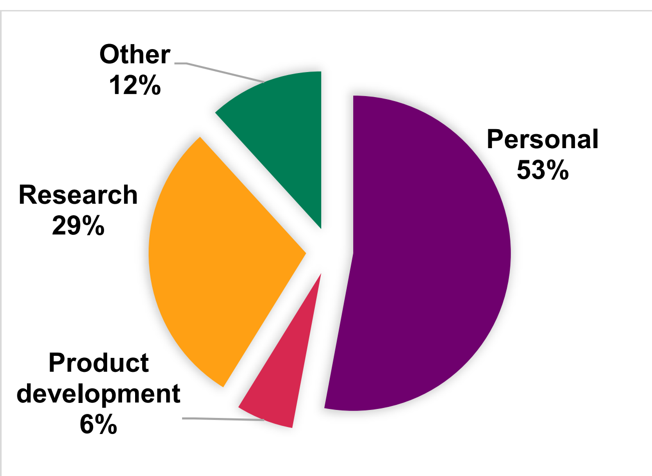

Figure 5. Survey respondent description of the purpose for borrowing a 3D printer.

Feedback received on the survey and in student interviews was very positive. The students indicated that they gained a better understanding of 3D technology and felt more confident in their abilities to operate and use tools to make minor repairs to the 3D printers. More instructional resources were requested and the library added additional resources to the LibGuide in response to this and other comments. While the survey had a small response, the feedback in combination with the constant high demand for the printers confirmed that there is a need for alternative 3D printing options and that students valued the active learning experience.

Teaching Building of 3D Printers Credit Course
While circulating 3D printers allows students to 3D print by themselves, it does not fully teach students how 3D printing works because, especially if the printer is fully operational, the process can still be mysterious. A one credit honors course was offered at UF in which 12 students spent the semester constructing a 3D printer. The course, *Exploring 3D with Building, Modeling, and Printing*, met for 50 minutes once a week for 16 weeks. In total, that amounted to approximately 10 hours for each group to build the 3D printer kit. The course was offered through the UF Honors Program which provides exceptional students with opportunities to enroll in small, challenging classes. To offer this honors course, the faculty librarians submitted and received approval for a proposal to the UF Honors Program outlining the course objectives, assignments, and outcomes.

Five iMADE3D Jellybox printer kits were purchased from iMADE3D at a cost of approximately $750 per printer (https://www.imade3d.com/). The printer kit components are well-labeled and the major pieces connect using zip ties and may be unassembled at the end of the semester by simply snipping with scissors. The sturdy, mostly acrylic components and usage of zip ties ensures that the class may be taught over again many times. The company provides 3D models and schematics so that components can be reprinted or laser cut if replacements are needed.

The Jellybox printer is designed to be assembled in about 8-12 hours. The extruder is completed and the wiring is bundled. The kit includes on-line instructions that are photo-based. The kits came with most of the tools needed including allen wrenches, spanner/pliers, screwdrivers, and wire cutters for zip ties. The class was taught in a library classroom equipped with large tables, which had computers for viewing the detailed instructions and downloading the printer software to slice the models.

Prior to the semester start, the instructor built a kit that served as an example model for the students to compare with their own build. The instructor mapped out the build steps to each class period so students could stay on track to complete by the end of the semester. Additional course objectives, if the printer was successfully built and calibrated, was to introduce 3D scanning and modeling with the resulting models being printed by the students on their printer. The class was limited to 12 students, who were split into 4 teams of 3 students. These were undergraduate honors students, 4 men and 8 women, with majors distributed between engineering, science, business and the arts. The class was very popular and filled up within two minutes of when registration was opened.

The first week of class, the students were given a skill survey to gauge their experience with hand tools and 3D technology. Weeks 2 through 15 were spent building the printers. Because the classroom was used by others during the week, the teams had to store their builds in a box until the next class. Week 16, the final class, was spent finishing any last builds, printing models, and exploring modeling and scanning.

There were a number of challenges in offering a new 1-hour course where students build a 3D printer in one semester. Although the skill survey in the first class suggested that most students lacked experience with tools, the instructor underestimated how much basic instruction was needed. However, by the semester's midpoint, each of the students had become proficient with basic tools, such as screwdrivers, pliers, and nuts and bolts. Realizing that soldering would go beyond the scope of the class and might be a fire hazard within the library, the instructor assembled and soldered wiring for the students ahead of time.

Course evaluations were completed by 33 percent of the class (4 of the 12 students). The overall ratings were excellent, receiving a 5 out of 5 in all 10 categories. Figure 6 presents the results of the evaluations. At the end of the semester, students felt much more confident in their mechanical abilities. They were able to follow detailed assembly instructions and use basic hand tools.

Term: Spring, *Course:* IDH3931 Honors Exploring 3D, *Sections:* 052C, *Enrolled:* 12							
Questions		Responded	Response Rate	Mean	Dept Mean	College Mean
1.	Description of course objectives and assignments	4	33%	5.00	4.72	4.40
2.	Communication of ideas and information	4	33%	5.00	4.73	4.26
3.	Expression of expectations for performance in this class	4	33%	5.00	4.69	4.36
4.	Availability to assist students in or out of class	4	33%	5.00	4.70	4.36
5.	Respect and concern for students	4	33%	5.00	4.80	4.43
6.	Stimulation of interest in course	4	33%	5.00	4.80	4.28
7.	Facilitation of learning	4	33%	5.00	4.72	4.24
8.	Enthusiasm for the subject	4	33%	5.00	4.86	4.47
9.	Encouragement of independent, creative, and critical thinking	4	33%	5.00	4.79	4.33
10.	Overall rating of the instructor	4	33%	5.00	4.79	4.30

Figure 6. Student course evaluations.

Conclusions

To provide an active learning experience and help our students build confidence in their mechanical abilities, the UF science and engineering library expanded its 3D service to add circulating 3D printers for students to check out of the library and learn how to print their own models. Taking the engagement one more level, the library also developed a credit course for students to deepen their understanding of 3D technology through building a 3D printer. By comparing the responses to the skill survey given to students during the first week of class and the feedback the students provided at the end of the class, the students increased their confidence level in their abilities to use hand tools and in their knowledge of 3D printing. Although the skill survey in the first class suggested that most students lacked experience with tools, by the semester's midpoint, each of the students had become proficient with assembly using screwdrivers and nuts and bolts.

Student feedback from the 3D printer check-out and the credit course showed that the active learning objectives were met in that the students increased their confidence in their mechanical skills and use of hand tools. They were also able to troubleshoot and develop typical repair strategies for the 3D printers and they gained experience in following detailed technical instructions.

The first printer build course was particularly insightful for the library faculty in that it showed how much the faculty initially overestimated the incoming student's baseline proficiently with basic hand tools, such as wrenches, sockets, and screwdrivers. Developing the tool skills necessary for the printer build subsequently proved to be a valuable active learning experience for the students, as well as a confidence builder.

While many research libraries provide 3D printing services, UF was the first university to provide portable 3D printers for check-out and one of the first to offer a class where students build a 3D printer. These services have helped center the engineering library within the network of university maker resources and, through these connections, have led to new instruction and research partnerships across campus.

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