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University Library Makerspaces: Create, Connect, Collaborate!

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Introduction

This paper examines the evolution of the University of Arizona Libraries' CATalyst Studios, conceived as part of the renovation of the Main and Weaver Libraries and construction of a new Student Success District (SSD). This was a seven-year, $81 million project that connected Main Library, the Weaver Science-Engineering Library, Bear Down Gym and the new Bartlett Academic Success Center. The Dean of University of Arizona Libraries Shan Sutton said of the District, which officially opened in April 2022: "The idea is, you've got cutting-edge innovative library renovations connected to student services that were previously scattered all over campus brought into one central location to make them easy to find and easy to use." This paper discusses CATalyst Studios, considered one of the real gems of the SSD, but will begin with a review of developments in the realm of makerspaces in academic libraries over time, with an emphasis on the way that these spaces have been used in engineering programs and pedagogy.

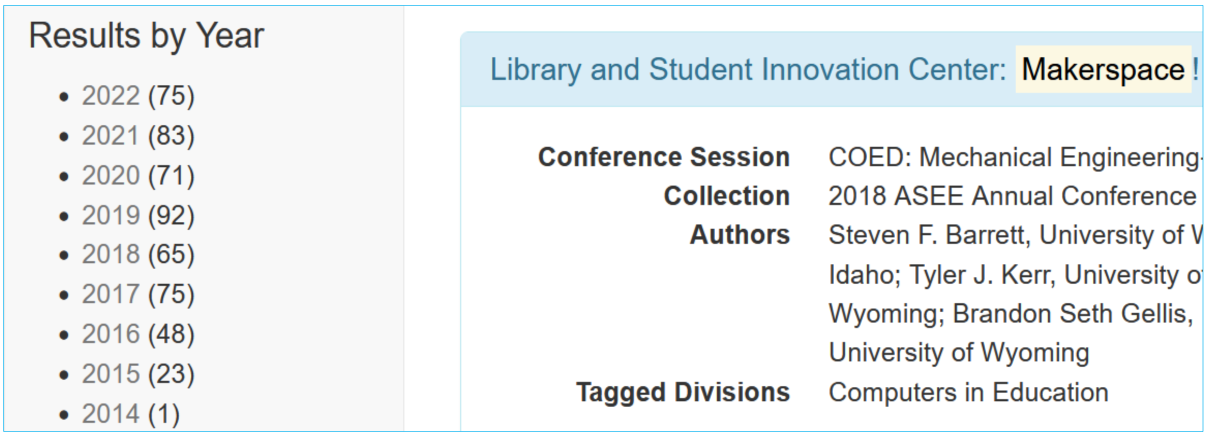
University Makerspaces: Brief History

Makerspaces as university resources are a relatively recent development, dating back to around 2001, when MIT opened its Center for Bits & Atoms [1]. By 2015, a section of the annual NMC Horizon Report: 2015 Higher Education Edition was devoted to a discussion of makerspaces. Horizon reports attempt to identify key trends and technologies impacting higher education, and it predicted that the time to adoption of makerspaces was two to three years. The report stated:

> The turn of the 21st century has signaled a shift in what types of skillsets have real, applicable value in a rapidly advancing world. In this landscape, creativity, design, and engineering are making their way to the forefront of educational considerations, as tools such as 3D printers, robotics, and 3D modeling web-based applications become accessible to more people. Proponents of makerspaces for education highlight the benefit of engaging learners in creative, higher-order problem solving through hands-on design, construction, and iteration. [2, p. 40]

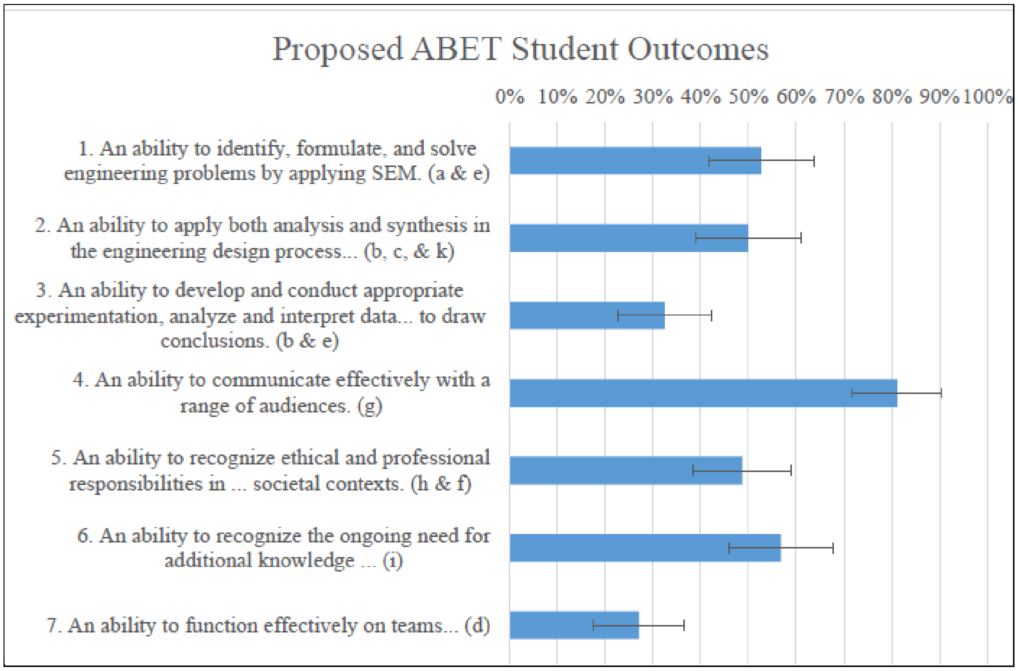
In 2005 **Make:** magazine began publication and started sponsoring "maker faires" around the U.S. and in other countries the following year [3]. In fact, **Make:**'s maker faires became so popular they caught the attention of the Obama administration, which held its own national White House Maker Faire in 2014. Public libraries were out front in embracing the maker movement, since their mission to serve as a hub for lifelong learning fit so well with one of the maker movement's foundational purposes: to provide anyone, of any skill level, an opportunity for self-directed learning. In response to the White House Maker Faire, over 100 Urban Library Council members signed a letter to President Obama in which they pledged their ongoing commitment to being centers for creative making.

Makerspaces have been called a variety of things – Fablabs, Idea Labs, Hackerspaces, Innovation Labs, to name a few – but in the ASEE PEER Document Repository, makerspace is by far the most frequently indexed term. When using "makerspace" as a search word in PEER, one can see the uptake of makerspaces within the domain of engineering education. From its first appearance in 2014 with a single paper having been indexed with "makerspace", within five years (2019) there were 92 papers. From that peak year, the number of papers has gone down slightly, but averages about 76 papers per year.



Indeed, the opportunities for makerspaces to support engineering student learning are immediately apparent with even the most cursory examination. In a 2016 paper entitled "How Can Maker Skills Fit in with Accreditation Demands for Undergraduate Engineering Programs?", Wigner et al. look at the skills makers learn and/or practice, and then categorize these according to how they align with existing and proposed ABET standards [4]. The authors define makers as individuals who have creative confidence, meaning they do not see failure as a problem, but rather as a necessary part of any design project. Makers are viewed as arising from the tinkering, DIY community but have instead a DIWO – Do It With Others – ethos. The primary components of the "maker mindset" are: a failure-positive approach to problem solving; collaborative knowledge sharing; and a sense of play. The authors use thematic analysis as the theoretical model for analyzing the artifact elicitation interviews with young (ages 12-17) and adult (18-60+) makers.

The chart depicting the authors' findings is below. Subsequent to publication of their results, the ABET learning outcomes have been revised. Wigner et al.'s paper references the outcomes in effect in 2014 in parentheses and charts results according to the proposed revisions. When the actual 2022-2023 learning outcomes are compared to those proposed, one finds very little divergence. Wigner et al. concluded that 75% of makers are learning how to communicate technical content to a wider audience; 50% are learning valuable techniques to foster their lifelong learning, how to apply engineering knowledge to solve problems, and are learning skills specific to electrical and manufacturing engineering; and 33% are working with multidisciplinary teams and are designing systems with realistic constraints. All of the 2022-23 ABET Student Outcomes in Criterion 3 [5] could potentially be achieved through a student engaging with a makerspace.



Wigner, et el., p. 13

2022-2023 ABET Criterion 3: Student Outcomes

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. an ability to communicate effectively with a range of audiences.
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Makerspaces open up creative possibilities for engineering students to access prototyping technologies. These can serve to supplement design courses, enabling more practice-based engineering to complement theoretical coursework. Barrett, et al. note that with the tightly packed curriculum of most undergraduate engineering programs, especially those with an emphasis on theory and mathematical modeling, many undergrads get little to no hands-on time designing and building until late into their degree programs [6]. Vincent Wilczynski, Director of Yale's Center for Engineering Innovation & Design noted:

> With the increased attention to the role of design throughout the engineering curriculum, the increased awareness of the value of active learning and team-based problem solving, the increased support for both faculty-led and student-led entrepreneurship activities, all coupled with the culture shift on college campuses influenced by the maker movement have played major role in inspiring universities to invest in Makerspaces. [7, p.1]

Makerspaces provide the setting where anyone, no matter their skill level, has the opportunity to learn by doing, and to get advice and support form peers in the process. As a 2013 Educause Learning Initiative Report states, "…makerspaces have become arenas for informal, project-driven, self-directed learning, providing workspace to tinker, try out solutions, and hear input from colleagues with similar interests. Where these spaces are open to use by faculty, students, and staff from a cross-section of content areas, they promote multidisciplinary thinking and learning, enriching the projects that are built there and the value of the makerspace as an educational venue [8]."

Makerspace Resources, Services and Staffing Models

There are several ways an academic library makerspace can provide academic support to engineering students. The makerspace may function to serve curricular needs, with activities geared around a particular course. This can vary from the makerspace being responsible for the teaching of a module within a course, to running a class in its entirety. An example of the latter would be the 1-credit honors "Exploring 3D with Building, Modeling, and Printing" course at University of Florida Libraries. Jean Bossart presented on this at last year's ASEE conference in Minneapolis [9]. Additionally, students can work on class assignments, refining their design instances, for example, prior to submitting the assignment. Makerspaces may also support the entrepreneurial interests of its users, providing students the space to prototype and create iterations of their inventions. Makerspaces can also supplement engineering students' education by providing a place for student clubs to gather. Individual students can use the makerspace as a creative outlet – a place to play around with ideas and if desired, a place to share these ideas with others.

Many makerspaces began with offering 3D printing services, and the DeLaMare Science and Engineering Library at University of Nevada-Reno was the first academic library to offer 3D printing to all its students in 2012 [10]. Lenton and Dineen observed that by 2014, 3D printers had caught on in academic libraries [11]. They noted, too, that service models varied by library, with some offering a mediated service, some offering a self-service model, and some libraries offering both. In Nagle's 2021 summarization of academic library makerspace case studies, she observed that from 2013 to 2016 the majority of case studies pertained to 3D printing, with a greater variety of equipment described in the case studies that followed [12].

As with the provision of any new service, infrastructure must be carefully considered. Makerspace implementation can only proceed with allocated funding for equipment, materials and personnel. Benjes-Small et al. reported in their study "Makerspace or Waste of Space: Charting a Course for Successful Academic Library Makerspaces" that hiring enthusiastic, self-motivated student employees goes a long way toward sustainably staffing a makerspace, and helping to prevent burn-out among regular staff [13]. So far as budgeting for makerspaces goes, Gonzales and Bennett suggest that donors be considered and cultivated, and that student fees, campus partnerships such as with the College of Engineering and fee for service are possible funding sources to be explored [14].

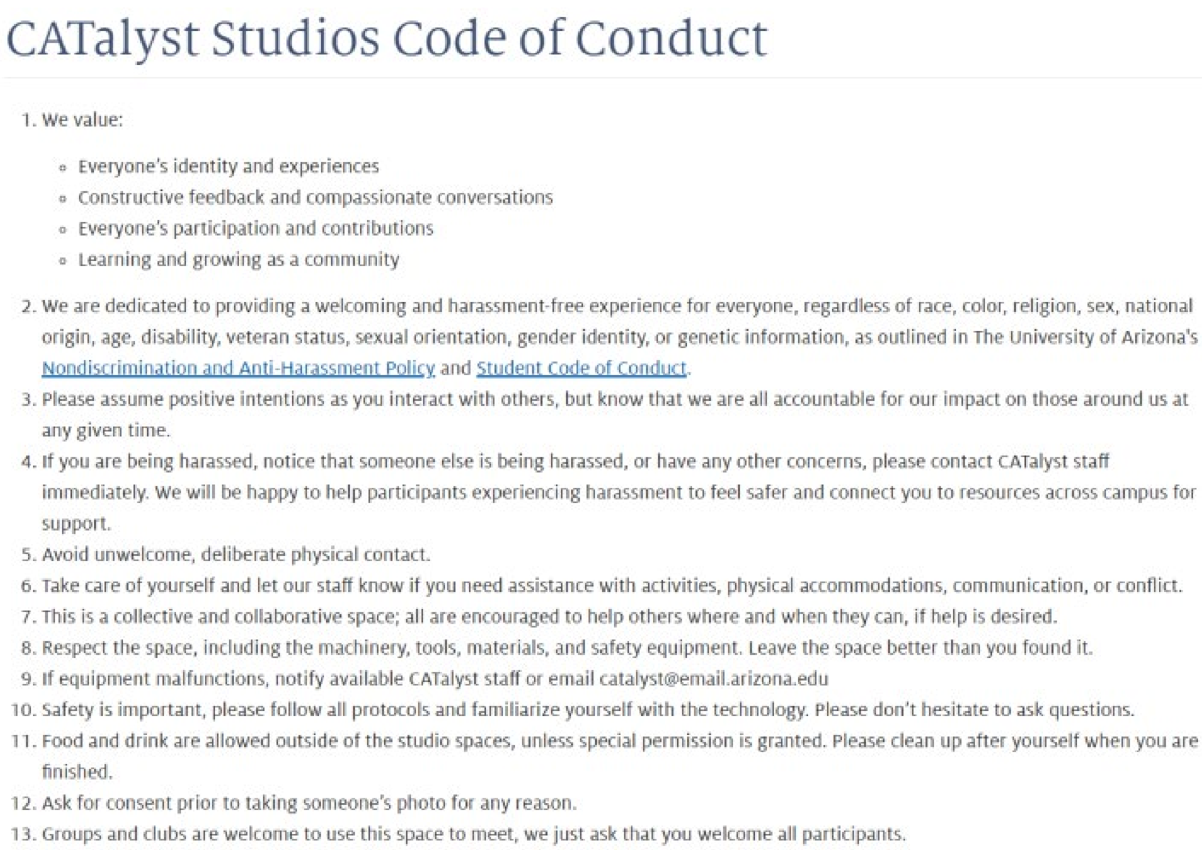
The CATalyst Studios at University of Arizona Libraries

The maker studios in University of Arizona Libraries (UAL) were a vital component of the multi-million dollar project to create a Student Success District, which collocates student support services such as tutoring, academic advising, student career development, disability support, the Writing Center, University of Arizona's Science, Engineering and Math Scholars Program, health and wellness center, and Serenity Space (supporting spiritual wellness) with spaces designed to facilitate collaborative, hands-on learning that promotes engagement with technology. The idea of a Student Success District (SDS) began to form when the national historic landmark Bear Down Gym (BDG) that sat between the Engineering and Science Library and Main Library was going to be renovated to include some student support services. UAL's Dean Sutton mentioned to colleagues in BDG that there were plans also underway for partial renovations of the two libraries "to create floors dedicated to collaborative, hands-on learning with various technologies in support of University of Arizona's curricular strategies and student learning priorities." [15] Through ongoing discussions, library leadership and colleagues in BDG recognized that there was a unique opportunity to use the mutual renovations in a more comprehensive way that would unite the three buildings into something that could better serve students by enabling "integration through adjacency". Furthermore, they thought, what about bringing the various student support services scattered around campus to this single location?

Working across units and with University administration, plans grew to include a fourth, newly constructed building sited behind BDG, that would house several offices that were dedicated to student success. The four buildings and the newly landscaped areas surrounding these buildings now comprise 8.5 acres. Owing to the clement weather in Arizona, the outdoor tables and seating areas supplement the new or renovated indoor spaces, all of which experience heavy use. One big reason the SDS was supported by campus administration was how closely the vision behind it aligned with institutional priorities. These priorities include: student recruitment and retention; collaborative learning; experiential learning; and technological skill building. Not only the district as a whole, but CATalyst Studios in particular, support all of these targets.

Some of the technologies found in CATalyst Studios include: 3D printing, CNC router and mill, industrial sewing and embroidery machines, button and jewelry making equipment, laser cutters, soldering tools and variety of hand tools, Arduino microcontrollers, computer aided design (CAD) software, Raspberry Pi, and vinyl cutters. The studios consist of the main makerspace, an AR/VR studio with workstations, a green screen cyclorama, a podcasting studio, and a computational and data visualization studio with a high-definition wall. As Educause reported: "Used by students, faculty, and staff, makerspaces have become arenas for informal, project-driven, self-directed learning, providing workspace to tinker, try out solutions, and hear input from colleagues with similar interests [8, p.1]." The maker studios in Main Library evolved from a small fab lab called iSpace, two rooms and approximately 600 square feet, that opened in 2014. The iSpace included maker tools, rapid prototyping equipment, 3D modeling software and printer, a data visualization wall, open-source computer and a VR studio. The iSpace was funded through a partnership with InnovateUA and the College of the Humanities. InnovateUA was under the Office of Student Engagement and was charged with providing all students with applied knowledge experience, prior to graduation. The College of Humanities was branching into digital humanities – "more hack than yack" – and was pleased to share the cost burden for necessary technology with the Library. The iSpace was operated by a couple librarians whose work allocations included overseeing the iSpace, along with several student employees and personnel from InnovateUA.

CATalyst, on the other hand, is structured with multiple levels of library-based employees, including two faculty, two staff, 14 undergraduate employees, one graduate student and five interns. It places an emphasis on self-directed learning that is supported by interaction with peers, and with student staff helping users discover new approaches to knowledge creation. The CATalyst Studios Code of Conduct gives a very clear sense of why and for what purposes the spaces were designed:


CATalyst Studios Code of Conduct

1. We value:
   - Everyone's identity and experiences
   - Constructive feedback and compassionate conversations
   - Everyone's participation and contributions
   - Learning and growing as a community
2. We are dedicated to providing a welcoming and harassment-free experience for everyone, regardless of race, color, religion, sex, national origin, age, disability, veteran status, sexual orientation, gender identity, or genetic information, as outlined in The University of Arizona's Nondiscrimination and Anti-Harassment Policy and Student Code of Conduct.
3. Please assume positive intentions as you interact with others, but know that we are all accountable for our impact on those around us at any given time.
4. If you are being harassed, notice that someone else is being harassed, or have any other concerns, please contact CATalyst staff immediately. We will be happy to help participants experiencing harassment to feel safer and connect you to resources across campus for support.
5. Avoid unwelcome, deliberate physical contact.
6. Take care of yourself and let our staff know if you need assistance with activities, physical accommodations, communication, or conflict.
7. This is a collective and collaborative space; all are encouraged to help others where and when they can, if help is desired.
8. Respect the space, including the machinery, tools, materials, and safety equipment. Leave the space better than you found it.
9. If equipment malfunctions, notify available CATalyst staff or email catalyst@email.arizona.edu
10. Safety is important, please follow all protocols and familiarize yourself with the technology. Please don't hesitate to ask questions.
11. Food and drink are allowed outside of the studio spaces, unless special permission is granted. Please clean up after yourself when you are finished.
12. Ask for consent prior to taking someone's photo for any reason.
13. Groups and clubs are welcome to use this space to meet, we just ask that you welcome all participants.

From the iSpace to CATalyst Studios was an exciting transformation, with university funding supporting much of the startup costs for CATalyst. Launching with a soft opening January 2020, COVID-19 and the subsequent campus closure in March 2020 meant that the grand opening was deferred until April of 2022.

Although UAL's CATalyst Studios were not able to make quite the splash they might have if the Pandemic had not kept the grand opening from coinciding more closely more with the soft opening, there was impact nevertheless. Once the campus reopened, liaisons actively promoted CATalyst in a variety of ways. One way liaisons did this was by including information about the library makerspaces whenever asked to do a library orientation or instruction session. It was after one of the larger orientations the author delivered to a group of ENGR 102 students in Fall 2021 that I connected with the professor who is chief administrator of this required first-year course. Following the orientation, he and I talked briefly about library resources, including CATalyst Studios – and I asked if he would like to bring students in for a tour or maker activity. Instead, the professor inquired about the 3D printing capacity, as the 3D printers available at the College of Engineering were prioritized for upperclassmen, and he would like the ENGR 102 students to have the opportunity to print something during the course unit on additive manufacturing. Further discussion led us to setting up a meeting with the director of CATalyst, one of her associates, another College of Engineering professor, and the College of Engineering Dean of Academic Affairs. The meeting began with a tour of the Studios and as this group explored the possibilities, it was eventually decided to run a pilot where the Spring 2022 ENGR 102 class would do their additive manufacturing unit at CATalyst, with library 3D printers and instructors. CATalyst Studios staff had already developed a certification program in 3D printing, so it was believed that the capacity existed to develop course modules on additive manufacturing. The spring semester has a much lower ENGR 102 enrollment than the fall semester, making it ideal to run a pilot program.

The pilot was designed so that students received a one-hour introduction to 3D modeling in one of the library classrooms adjacent to the studios. This was followed by small group hands-on training on the use of two of the FDM printer types available – Ultimaker S3 and Zortrax M300 – where they learned how to position, size and customize printer settings. Students were then required to attend an hour-long class that covered safety issues, as well as how to load and run print jobs. During this session, students were also given troubleshooting tips. The small groups received a certification if they completed all the above and ran a successful test print. With this certification, students could use the 3D printers at CATalyst without supervision. They also got documentation that they were now certified, which was shared with their professors and with the University's student career development program. Once certified, the small groups designed a 3D model which fulfilled the requirements of the ENGR 102 final project, and printed these at CATalyst Studios.

CATalyst staff assessed the pilot in conjunction with engineering faculty in order to determine what changes might be necessary to scale up for the much larger fall (500+ students) cohort. An obvious possibility was to do more with online and video tutorials. The library's Instructional Design & E-Learning unit created a sequence of online/video tutorials that cover things such as an introduction to 3D printing concepts and terminology, how to splice 3D models in Ultimaker Cura and Z-Suite software, etc. The complete tutorial set is available for use by anyone with this link: https://new.library.arizona.edu/tutorials/3d-printing/ Following the students' completion of a quiz of their understanding of the tutorial content, students were then moved on to the final hands-on portion of the training where they would set up and oversee a 3D print. Throughout the semester, ENGR 102 students could attend multiple drop-in help sessions, getting questions answered about the 3D printing process, as well as questions specific to their small group projects.

This 3D printing ENGR 102 certification program meets several library objectives. Engineering students had an experiential learning unit conducted in the university library's makerspaces, while CATaylst staff was forging a collaborative relationship with College of Engineering faculty. Objectives met: facilitate experiential learning and form collaborative relationships with University instructors. The certification the students received may be used on a resume, meeting the objective of supporting student success. As importantly, the library's 3D printing class module supported the overall learning objectives of ENGR 102: to be able to use the engineering design process to meet expressed needs; to become effective team members; to become effective communicators, and; to understand the fundamental principles that support learning and become lifelong learners.

While learning about and using the 3D printers - two of which were purchased by the College of Engineering - in the library's maker studio, this freshman class was exposed to all of the technology they have access to in the makerspace, and an outcome of this has been the development of ad hoc communities of practice. Engineering students have also used CATalyst for recreational purposes and as a creative outlet. The CATalyst staff surveyed students who went through the certification program, and the majority felt confident they can 3D print something, they believe they can learn other 3D printing models, and they thought the program was a good use of their time. This hits the objective for student engagement. The College of Engineering is currently raising funds to build a large Student Design and Innovation Center which will have many 3D printers, but when asked if ENGR 102 students would be taking their additive manufacturing unit there, once available, the professor overseeing this course said no, because he was really glad that freshmen were being "forced" to go to the library during their first semester on campus. The exposure and (hopefully) positive experience with the people and resources available would set them up to be users of the library for the rest of their undergraduate careers.

Future Directions

ENGR 102, required course for all freshmen attending the College of Engineering, will continue to have the Additive Manufacturing unit delivered through University of Arizona Libraries/CATalyst Studios. CATalyst staff will continue collaborating with engineering faculty to ensure the training they have created satisfies the course learning outcomes and is rated well by students. Enhancements to the makerspaces will continue to be made in response to user wishes. For example, the podcasting studio will be moved into its own soundproof space (it shared a room with the green screen and a music keyboard station) because of the high demand for it. Workshops and events will continue to be responsive to user interests. For example, an affinity group – oSTEM – recently formed for out STEM students who want to use the makerspace to gather and create things using button making, jewelry making and screen printing. It is hoped that the makerspace will continue to foster interdisciplinary collaboration among its users. The benefits of makerspaces include the development of practical skills, the promotion of interdisciplinary collaboration, the encouragement of entrepreneurship, community engagement, and the enhancement of the university's reputation. These collaborative makerspaces provide engineering students with the practical skills and soft skill experiences needed to succeed in today's innovation-driven economy. UA Libraries believe that by offering engineering students – and their peers in other disciplines – access to many types of technology, University of Arizona Libraries' makerspaces level the playing field, making tech learning opportunities readily accessible.

References

[1] D. Slatter and Z. Howard, "A place to make, hack, and learn: makerspaces in Australian public libraries," *The Australian Library Journal*, vol. 62, no. 4, pp. 272–284, Nov. 2013, doi: 10.1080/00049670.2013.853335.

[2] *NMC Horizon Report: 2015 Higher Education Edition*. Austin, TX: New Media Consortium, 2015. https://eric.ed.gov/?id=ED559357

[3] C. Anderson, *Makers: the new industrial revolution*. New York, NY: Random House; 2012.

[4] A. Wigner, M. Lande, and S. Jordan, "How Can Maker Skills Fit in with Accreditation Demands for Undergraduate Engineering Programs?," in *2016 ASEE Annual Conference & Exposition Proceedings*, New Orleans, Louisiana, Jun. 2016, p. 25468. doi: 10.18260/p.25468.

[5] ABET Engineering Accreditation Commission, 2022-2023 Criteria for Accrediting Engineering Programs; 2021. https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2022-2023/.

[6] T. Barrett *et al.*, "A Review of University Maker Spaces," in *2015 ASEE Annual Conference and Exposition Proceedings*, Seattle, Washington, Jun. 2015, p. 26.101.1-26.101.17. doi: 10.18260/p.23442.

[7] M. Galaleldin, F. Bouchard, H. Anis, and C. Lague, "The Impact of Makerspaces on Engineering Education," *PCEEA*, Jan. 2017, doi: 10.24908/pceea.v0i0.6481.

[8] "7 Things You Should Know About Makerspaces," *Education Learning Initiative*, p. 2, 2013, https://library.educause.edu/resources/2013/4/7-things-you-should-know-about-makerspaces.

[9] J. Bossart and S. Gonzalez, "Promoting active learning in an engineering library," in *2022 ASEE Annual Conference & Exposition Proceedings*, Minneapolis, Minnesota, June 2022. https://peer.asee.org/promoting-active-learning-in-an-engineering-library

[10] C. Wapner, "3D Printing Policy Considerations through the Library Lens," OITP Perspectives, no. 3, 2015, https://www.ala.org/advocacy/sites/ala.org.advocacy/files/content/advleg/pp/pub/perspectives-3D_Library_Policy-ALA_OITP_Perspectives-2015Jan06.pdf .

[11] E. Lenton and C. Dineen, "Set it and Forget it (Almost): How We Make DIY 3D Printing Work in Our Library," *Public Services Quarterly*, vol. 12, no. 2, pp. 179–186, Apr. 2016, doi: 10.1080/15228959.2016.1168725.

[12] S. B. Nagle, “Maker Services in Academic Libraries: A Review of Case Studies,” *New Review of Academic Librarianship*, vol. 27, no. 2, pp. 184–200, Apr. 2021, doi: 10.1080/13614533.2020.1749093.

[13] C. Benjes-Small, L. M. Bellamy, J. Resor-Whicker, and L. Vassady, “Makerspace or Waste of Space?,” *in 2017 ACRL Biannual Conference & Exposition Proceedings,* Baltimore, Maryland, March 2017. https://alair.ala.org/handle/11213/17757

[14] S. R. Gonzalez and D. B. Bennett, “Planning and Implementing a 3D Printing Service in an Academic Library.,” *ISTL*, no. 78, Dec. 2014, doi: 10.29173/istl1619.

[15] S. Sutton, “The University of Arizona Student Success District: Vital Signs of Library Alignment with the Institutional Vision at Scale,” in *Designing Libraries for the Twenty First Century*, H. Hickerson, J. Lippincott and L. Crema, Eds. Chicago, IL: ACRL, 2022, pp. 79-88. https://bit.ly/DesigningLibraries