# Experiential Learning in the Curricula: Integrating the Makerspace into First-Year Engineering Coursework

## 6th International Symposium on Academic Makerspaces

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Rachel Castro[1], Jennifer Nichols[2]
[1]Rachel Castro; University Libraries, University of Arizona; e-mail: castro2@email.arizona.edu
[2]Jennifer Nichols; University Libraries, University of Arizona; e-mail: jtn@email.arizona.edu

## Introduction

Makerspaces are universally known as sites of hands-on exploration and problem-solving. In an academic makerspace, students often apply theoretical learning and build technical and design skills. In CATalyst Studios at the University of Arizona libraries, deliberate engagement with instructors to integrate makerspace technology and design thinking into the curricula strives to extend the benefits of experiential learning and introduce students to opportunities to collaborate with others and apply their learning. One example is highlighted in this paper; a pilot program CATalyst Studios has co-designed with Engineering professors as an integration to bring all first-year students into the makerspace to learn how to 3d print.

## CATalyst Studios

CATalyst Studios is an interdisciplinary maker space and digital learning studio in the Main Library of the University of Arizona in Tucson, Arizona. The studios include a comprehensive maker studio, an AR/VR studio with workstations, a green screen cyclorama and a podcasting studio, and a data visualization studio with a high-definition wall. The facilities are open to all members of the community, with a focus on serving students at the University.

Principally, the Studios support learning communities who want to explore together and learn from one another. As is central to any makerspace, the community members who use CATalyst Studios have access to other numerous tools and emerging technologies, including fabrication tools like 3d printers, laser cutters, sewing machines, and vinyl cutters. At the core of what CATalyst has created however, is an inclusive and equitable space that strives to welcome users of any level.

CATalyst is structured with multiple levels of support, including two faculty, two staff, 14 undergraduate students, a graduate student and 5 interns. Students staff the space and run certification workshops, and are encouraged to cultivate projects, collaborations, and new directions for CATalyst as a regular part of operations. Within the interdisciplinary communities of self-directed learning supported in CATalyst, student knowledge is reinforced as valuable. Students help one another solve problems, learn new skills, and connect with what they are learning in a new way.

## Why is Experiential Learning Important?

Experiential learning, or the combination of using lived experience and/or hands-on, interdisciplinary, project-based work to create new learning applications, is not a new concept by any means [1]. Experiential Learning Theory (ELT) was developed in 1971 by educational theorist David A. Kolb [2]. Kolb created a four-stage process that a learner goes through called the Learning Spiral [2], which includes Concrete Experience (having an experience), Reflective Observation (reflecting on that experience), Abstract Conceptualization (processing the reflection into a new iteration or idea), and Active Experimentation (trying out a new or revised approach). Utilizing the experiential learning in makerspaces, the learner is allowed to approach learning as a continual process instead of an "input in and out" process where they are required to come to a singular correct outcome. Instead, students engage in holistic processes where they create and adapt knowledge, synthesizing their learning through the whole self—thoughts, feelings, perceptions, and behavior—and apply it to real-life situations [3].

Kolb also outlines four learning styles, or preferred ways of learning from experience, influenced by the situation, social environments, and previous exposure to learning environments. These learning styles are labelled as Diverging (feeling and watching), Assimilating (think and watch), Converging (think and do), and Accommodating (feel and do) [4]. The spaces in which students are encouraged to learn are very interdependent with what type of learning with which they will engage. Maker culture is a confluence of learners with various levels of expertise, with a focus on building knowledge, building connections, and creating artifacts toward personal or professional goals. Beyond engagement with the various forms of ELT learning styles, a maker space can also create a sense of community for students, providing an opportunity for membership into a group of learners with which they can continually build mastery and expertise.

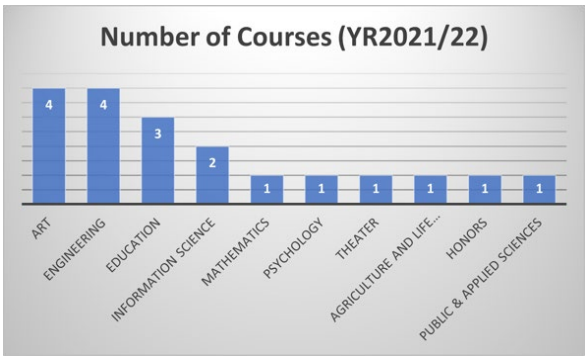


Fig. 1 Number of Course Integrations in 2021/22

Interest in using experiential learning as a tool for student success as they navigate the fourth industrial revolution has risen exponentially in the last decade. It has been adopted across all areas of higher education as a form of student-centered learning that provides students with the opportunity to interpret and process content on their own. The incorporation of experiential learning in curriculum can result in the creation of industry-specific skills and knowledge, transferable competencies that can apply to professional life, and the ability to problem-solve in real-time with creativity and collaboration. In response, the University of Arizona has added experiential learning to the Arizona Advantage pillar of their strategic plan [5], and the University of Arizona Libraries has created an Experiential Learning Unit during their 2021 restructuring, under which the Director of CATalyst Studios and the new role of Experiential Learning Librarian fall [6].

## Experiential Learning in CATalyst Studios

In March of 2020, the University of Arizona closed campus in response to the novel Coronavirus. CATalyst Studios, in its first months of operation, was closed for eighteen months and reopened in August 2021 for the Fall semester. During closure, the University Libraries restructured, and CATalyst Studios was nested under the Student Learning & Engagement Department as the Experiential Learning Unit. This change offered the opportunity to deeply enhance curricular engagement with instructors across the institution.

The University of Arizona Libraries had previously supported experiential learning in its first makerspace, iSpace, piloted from 2015-2019. In these years, humanities faculty collaborated to integrate virtual reality and prototyping into their curriculum, collaborating with librarians and establishing a precedent for this type of learning to happen in the library makerspace context [4].

Despite not actively seeking out new relationships on campus there was an instant, growing demand from instructors to bring students into CATalyst and to incorporate some form of hands-on learning into syllabi. In Fall of 2021 CATalyst worked with eleven individual courses, arranging tours, workshops, and activities for over four hundred students across twenty visits. In Spring 2022 CATalyst Studios worked with eight distinct courses, resulting in 27 visits with a total of 420 students visiting the various studios and classrooms. Figure 1 outlines total course integrations for the Fall 2021 through Spring 2022 semesters. Figure 2 demonstrates the proportions of students per discipline.

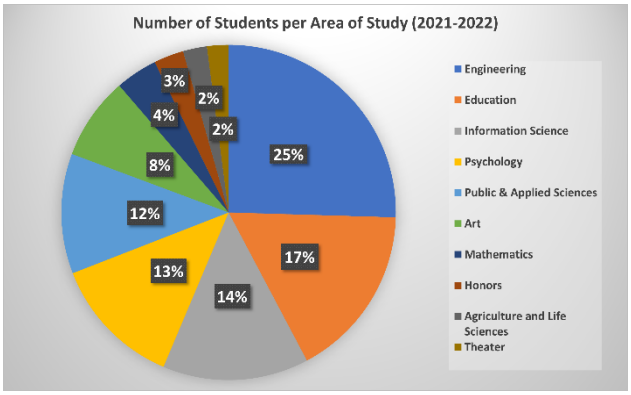


Fig. 2 Number of Students per Area of Study in 2021/22

## Engineering 102 Case Study

3D printing had become a core tool for experiential learning across many disciplines but is of particular interest to engineering students and faculty at the University of Arizona. As educational technology, 3D printing incorporates collaboration, problem solving, critical thinking, and creativity through the design and manufacturing process [7]. As a maker space, CATalyst has provided support for situated, experiential, and self-directed learning for engineering students working on projects, which all provide the benefit of creating a physical or virtual object and encouraging the practical application of skills and resources.

Toward the end of the Fall 2021 semester CATalyst Studios was approached by Profs. Umar Amjad and Hannah Budinoff, instructors for the mandatory, introductory course Engineering 102 (ENGR 102). They asked CATalyst to pilot a new program to certify every student taking ENGR 102 in 3D printing, culminating in a group project where teams would print a custom design. While it is not unusual for makerspaces to work with engineering students on individual and course-based projects, this project provides CATalyst Studios the opportunity to host and train every undergraduate engineering student early in their academic career, creating a stream of new, connected, and empowered users. This outcome aligns well with the University of Arizona Libraries' and CATalyst Studio's mission of encouraging student success and in-depth engagement.

## Methodology (Spring 2022)

The pilot entailed an in-person, one-hour introduction to 3D modeling for printing and then small group, hands-on training

on how to use the 3D printers. Students were introduced to 3D printing, considerations for designing a 3D model that can be successfully printed and were guided through the process of setting up a print with the two FDM printer types in CATalyst—Ultimaker S3 and Zortrax M300. Demonstrations of slicing software Ultimaker Cura and Z-Suite included instructions for how to position, size, and customize the settings for 3D printers.

All students were then expected to attend an hour-long in-person training session to learn about safely and properly loading materials, running print jobs, and troubleshooting common printer issues. After small groups successfully ran a test print, they were awarded a certification. All students had a notation added to their library account, which would allow them to use the 3D printers at CATalyst Studios without supervision and were provided digital certificates of completion. The certificates of completion were created at the end of the training period and shared with instructors, to be posted in the course learning management system D2L (Desire2learn) and Handshake, the University of Arizona student job board and career development platform.

Following certification, teams designed a 3D model that fulfilled the specifications of the final project of the ENGR 102 course and brought their project files to CATalyst for printing.

In April of 2022, CATalyst staff conducted an interview with the engineering faculty teaching the course to assess whether the initial approach met the needs of the course.

The second iteration of this process will take place in the fall semester of 2022, after which additional assessments, including a second interview and student survey will take place.

## Results

The in-person trainings were offered over a two-week period by CATalyst Student workers and accommodated up to 12 students per training. These were effective for most students, but evidence shows that students still need significant assistance to run a 3d print after initial training. Anecdotal evidence suggests students need to run two or more prints before feeling confident in their abilities to successfully operate the machine independently. Additionally, the hands-on training is time-consuming, and in preparing to scale up, there is consideration of adding even more online training modules to reinforce the learning and ensure all students are successful in retaining the necessary knowledge to be successful.

Aside from a small handful of students, who could not attend any of the twelve planned sessions and arranged other training sessions with CATalyst staff, the engineering students completed their certification and had approximately two months to complete printing their custom 3D designs.

CATalyst staff met with instructors toward the end of the spring semester to assess the pilot and consider changes for the fall. To better accommodate the large numbers of students, CATalyst collaborated with the library's Instructional Design & E-learning Unit to design online modules to introduce the concepts and terminology of 3D printing, and how to splice 3D models in corresponding software Ultimaker Cura and Z-Suite. Students must watch all four tutorials and complete an assessment of their understanding. When the assessment is complete, their personal information is relayed to a database and this information is used to confirm eligibility for the final hands-on portion of the training. A drop-in help session will be scheduled throughout the semester, providing the opportunity for clarification and questions regarding using CATalyst 3D printing services and team projects, after which students will sign up to attend a in-person portion of 3D printing certification that will provide hands-on experience setting up a 3D print and overseeing the printing process.

## Future Work

CATalyst staff are planning to launch the newly developed online modules for 3D printing certification within the first week of the fall semester. Upon launch, these modules will be available for use by anyone with the following link: https://new.library.arizona.edu/tutorials/3d-printing/.

The second iteration of the 3D certification process for student in the Engineering 102 course will take place between the first week in September to the first week of October. After students have completed the certification process CATalyst staff will conduct a second interview with the engineering faculty to gather additional feedback and explore further ideation. CATalyst Studios will also send out a survey to students in the ENGR 102 course to assess the success of the online and hand-on learning portions of the training, and whether the expected learning outcomes and mastery were achieved. The data from the second interview and student survey will be analyzed and presented at the 6th International Symposium on Academic Makerspaces in November 2022.

## Summary

Makerspaces are, by default, sites of experiential learning, and with deliberate curricular engagement, the benefits can extend to students in a variety of disciplines. With the integration into this required, first-year engineering course, students can not only learn about the resources available to them for the course of their undergraduate studies, but also to integrate and learn with interdisciplinary teams.

The 3D printing certification training program allows engineering students to build mastery in an in-demand skill

and provide them with both the knowledge of and ownership over CATalyst Studios and the University of Arizona Libraries as a, open, collaborative, and resource-rich space. This type of integration requires dedicated planning and collaboration with instructors at the onset, though the model can be replicated and implemented beyond the original site and semester.

All the curricula and training resources developed for this program will be available as open-source materials in the near future.

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