Makerspaces vs Engineering Shops: Initial Undergraduate Student Impressions

Kate Youmans
Department of Engineering Eduaction
Utah State University
Logan, Utah, USA
kate.youmans@usu.edu

Idalis Villanueva
Department of Engineering Education
Utah State University
Logan, Utah, USA
idalis.villanueva@usu.edu

Louis Nadelson
College of Educatoin
University of Central Arkansas
Conway, Arkansas, USA
louisnadelson@gmail.com

Jana Bouwma-Gearheart
College of Education
Oregon State University
Corvallis, Oregon, USA
Jana.Bouwma-Gearhart@oregonstate.edu

Adam Lenz
College Of Education
Oregon State University
Corvallis, Oregon, USA
lenza@oregonstate.edu

Sarah Lanci
Department of Mechanical Engineering
Colorado Mesa Univsersity
Grand Junction, Colorado, USA
slanci@coloradomesa.edu

***Abstract*— Makerspaces are a growing trend in engineering and STEM (Science, Technology, Engineering and Math) education at both the university and K-12 levels. These spaces which, in theory, are characterized by a community of likeminded individuals interested in digital fabrication and innovative design, are argued to provide opportunities to foster the skills sets critical to the next generation of engineers and scientists. However, spaces for making are not new to the engineering curriculum as many engineering programs have well-established machine shops or project labs that students utilize to complete course projects. In this work-in-progress exploratory study, the authors evaluated early undergraduate students' perceptions of two contrasting spaces, a contemporary makerspace and a traditional engineering shop. As part of an Introduction to Engineering course, students were asked to visit the two campus spaces, identify important equipment and policies they noticed in each space, and describe their perception of how the spaces were similar or different. Based on our initial findings, we speculate that access and safety issues in engineering shops may limit their use by early year engineering undergraduates. Alternatively, digital fabrication technologies and community culture in makerspaces can provide access to a hands-on prototyping and collaborative learning environment for early year engineering students.**

Keywords*—*Makerspaces, Engineering Shops, Early Undergraduates

I. Introduction

Beyond affording engineering students the opportunity to enhance their technical skills, makerspaces and other hands-on spaces like engineering shops are touted for their potential to engage students in collaborative activities that allow them to develop skills such as teamwork, problem-solving, and creativity [1]-[5]. However, spaces that allow opportunities to create and make are not new to the engineering curriculum, as many engineering programs have well-established machine shops or project labs used to support course projects [3]. Contrary to the open community-learning atmosphere in makerspaces, however, machine shops and project labs are often reserved for upper-level students to complete design projects and may contain complex equipment that requires specialized training to use [6]. Given the wide range of equipment, layouts and cultures found in maker-based learning environments, we believe it is important to capture students' perspectives of these diverse spaces. Specifically we seek to understand students' initial impressions of the differences between a traditional engineering shop and a contemporary makerspace in terms of safety, access, environment and types of projects offered. To do so, an open-ended survey was constructed and administered as part of a homework assignment in an Introduction to Engineering course at a western institution in the U.S. A total thirty-three responses were collected and analyzed qualitatively using a blend of a-priori and versus coding. This preliminary work suggests that students view traditional engineering shops as having higher risk and limited access, with a value attributed to learning machining methods for industry. On the other hand, students viewed contemporary makerspaces as more accessible for early year students to work on smaller and/or digitally fabricated projects.

II. Background

A. Makerspaces

The maker movement originated in the early 2000s as groups of individuals started leveraging new developments in digital fabrication and rapid prototyping techniques as a way to engage individuals in the process of making. The idea of fabrication labs (FabLabs) in engineering education was first introduced at MIT in 2001 to support the popular course "How to Make (Almost) Anything", which was intended to familiarize students with new forms of digital fabrication and rapid prototyping [7]. Physically, makerspaces can take on many forms, from smaller student-run labs to larger prototyping centers. In a study of university makerspaces, Barrett et al. found that the most common tools in makerspaces were whiteboards, computers and 3D printers [4]. These tools provide an opportunity for students to bring their creative ideas to life while at the same time engaging with emerging technology. Makerspaces do not need to be elaborate shops with extensive tools, but rather a space that promotes creativity and building. Sheridan et al. [8] define a makerspace as:

"informal sites for creative production in art, science, and engineering where people of all ages blend digital and physical technologies to explore ideas, learn technical skills and create new products" [p. 505].

These spaces are grounded in the education theories of Dewey, Piaget and Montessori, which promote learning through design, construction, and play [9]. By participating in makerspace activities, students may be exposed to the maker mindset, which supports growth through failure, shared problem solving and creative innovations [1],[8]. An integral characteristic of makerspaces is their collaborative nature, which involves problem solving in groups, often with diverse approaches or backgrounds [10]. This collaborative problem solving helps develop how students hone their abilities to work in teams and their development of effective communication skills.

Research by Wigner et al. [2] evaluated how being involved with making projects could address the ABET criterions 1 to 7. The study found that 76% of respondents shared that making helped them communicate technical ideas effectively (ABET criteria 3). In addition, 55% of respondents suggested that making helps them build lifelong learning skills (ABET criterion 5). Further, 57% and 49% of responded said that making helped them understand electrical and computer engineering and manufacturing engineering respectively. Additionally, the maker culture encourages individuals to work on project of their own interest and design. This strategy for helps bridge the gap between informal and formal learning environments [11], [12]. In bridging this gap students are often more motivated in their learning, find autonomy in working through failure, and improve their self-efficacy related to tools and technology [9], [11], [13].

With the decreasing cost of rapid prototyping technology schools and students can gain easier access to these technologies making it more feasible to implement makerspaces accessible to all university students [8]. In a recent study Barret et al. [4] found that 35 of the top 100 engineering schools as ranked by US News and World Reports promoted having makerspaces on campus. However, the number of these spaces can be difficult to quantify as they are often dispersed across campuses and do not always have "makerspace" in their nomenclature [4], [13]. With their growing popularity on university campuses, makerspaces have an opportunity to engage engineering students in experiential and hands-on learning, fostering engineering competencies, which are currently underdeveloped in engineering education [5], [12].

B. Engineering Shops

Dating back to the establishment of engineering as an educational discipline, engineering shops have served an important role in the engineering curriculum [3]. A post-World War II shift moved engineering away from the model of hands-on apprenticeship and towards a more theoretical classroom setting. This shifted the engineering curriculum to a more analytical emphasis that established the focus on didactic lecture style learning of the engineering sciences [14]. Efforts to re-engage student in hands on active learning in lab and shop settings resurfaced in the late 1990s following the modification of ABET to a quality-oriented accreditation criterion. Along with this change came a renewed emphasis on the importance of design in engineering (contrasting the previous focus on engineering sciences) and the implementation of many senior capstone design courses and first year design courses [3].

With the implementation of capstone design projects, especially in mechanical engineering, engineering shops play a critical role in introducing students to the manufacturing processes and real-world applications of their designs. These spaces can bridge the gap between traditional engineering sciences and their critical counterpart engineering technology [5]. Additionally they can introduce students to the manufacturing processes used in industry giving them a greater sense for design for manufacture requirements [15]. Involving students in engineering shops gives depth and context to their engineering sciences studies and creates a more well-rounded engineering student.

However, these shops differ from their makerspace counterparts in terms of equipment and environment. Equipment typically found in these spaces include large metal and wood working machinery and occasionally large CNC equipment representative of industry. The safety concerns and scale of equipment can lead to an intimidation factor for students who are not familiar with the equipment and environment [6]. For this reason, many engineering shops have strict training rules and limit access [16]. Several engineering programs have introduced a preliminary manufacturing (often in the junior year) which is intended to familiarize students with equipment and manufacturing processes before their senior capstone project [6], [17]. These spaces have the potential to engage students in hands-on learning, but barriers to entry including safety, training and access requirements may exist.

III. Methodology

Given the wide range of equipment, layouts and cultures found in maker-based learning environments and shops, the authors maintain it is important to capture students' perceptions of these spaces. Using a comparison framework, the authors sought to understand the differences in the way that students perceive the environment, project types, safety, and access between a contemporary makerspace and a traditional engineering shop. As these spaces can play a valuable role in an engineering students' education, it is important to evaluate these spaces through the lens of students by keeping in account their varied voices and impressions. For this reason, the authors opted to use a qualitative case study approach utilizing an open-ended survey to address the following research question:

Central Research Question:

In what ways do students' initial impressions of a contemporary makerspace and traditional engineering shop within a university environment differ with regard to types of projects, equipment, safety and access?

A. *Participants and Context:*

The case for this study is bound to the students enrolled in an introductory engineering course taught in a western institution in the United States during the Fall 2017 semester. This course is designed to introduce undeclared or undecided students to a broad range of engineering fields. As part of the course, students are introduced to engineering disciplines and engineering functions including production and development. The demographics for the course are provided below:

Gender: Male (n=37), Female (n=4)

Grade Level: Freshman (n=11), Sophomore (n=21)
Junior (n=7) Senior (n=2)

B. *Data Collection:*

Data for this study were collected as part of a homework assignment for this introductory course under Institutional Review Board approval and guidelines.

For this assignment, students were asked to visit two on-campus spaces for making. The first space was a recently opened (Fall 2017) contemporary makerspace with an emphasis on digital fabrication. For the purpose of this work, the pseudonym "Makerspace" will be used. The second space was a traditional machine shop housed in the same engineering college of this institution and is intended to support senior capstone projects. For the purpose of this work, the pseudonym "Engineering Shop" will be used.

After visiting each site, students were asked to compare and contrast the two spaces by answering the following questions:

- Describe the two lab spaces including what equipment is available and what policies students should be aware of.
- Describe how the two spaces are similar or different.
- Which of the two spaces (Makerspace and Engineering Shop) seem the most interesting and/or useful to you?
- Thinking about the function of development or production, how do you think using these spaces would help prepare you?

Thirty-three responses from the homework assignment were collected and de-identified prior to analysis. In the first round of coding, descriptive methods were used to identify the context of safety, access, types of projects and environment. The researchers then applied a blend of *a priori* and *versus* coding to compare the elements of safety, access, equipment and types of projects between the two spaces. This coding was completed in MAXQDA 2018 mixed method software and an inter-coder agreement of 93% was achieved. During coding, the researchers were careful to recognize their own positionality as engineering educators who have experiences using, developing and teaching within makerspaces and engineering shops.

IV. Results

Two main themes were identified from coding. The first distinction students identified was the nature and scale of projects typically found in each space, while the second distinction recognized the differences in safety and access between the two spaces.

A. *Theme 1: Nature and Scope of Projects*

The first key observation students made was about the nature of projects, which are typically created in each space based on the equipment and scale of the space. The students recognized the makerspace was a place to work on computerized or robotics projects that had a culture to foster group work, idea generation and innovation. This is in contrast to the engineering shop, which students identified as a tool for learning about manufacturing and production with more large-scale equipment and projects. Some example quotes to reflect these findings are summarized in Table 1.

TABLE I. INITIAL IMPRESSIONS ABOUT CONTEMPORARY MAKERSPACES AND TRADITIONAL ENGINEERING SHOPS ON NATURE AND SCOPE OF PROJECTS

Student Quote Examples about Nature and Scope	
Makerspace - Nature and Scope	***Count***
"I think that the [Makerspace] is excellent for development of smaller-scale or more personal ideas, focusing heavily on innovation." – Participant 19, Line 118 *"The [Makerspace] looked like it was mostly for research and designing of projects in the beginning stages and mostly small scale things."* – Participant 25, Line 150 *"The [Makerspace] was very artistic and designed to help you think and create new things."* – Participant 30, Line 178	66
Makerspace- Tools and Equipment	***Count***
"The [Makerspace] has a lot of tools such as drills, soldering irons, and other hand tools as well as several computerized machines like a laser cutter, CNC router, Vernier sensors and a PCP rework station. There are also tables to work on designs or plan and brainstorm." – Participant 10, Line 69 *"The [Makerspace] is a small space designed around computer technology. Almost all of their equipment is run from or set up by a computer. Their machines consist of engraving, cutting and soldering instruments*." – Participant 04, Line 25	
Engineering Shop - Nature and Scope	***Count***
"[Engineering Shop] is less for innovating and creating ideas, and more for actually bringing your ideas to life." – Participant 30, Line 179 *"The [Engineering Shop] is a larger more open space, and it appears to be designed for larger scale projects with wood or metal.*" – Participant 27, Line 166 *"Also, the [Engineering Shop]is a lot dirtier and more of a messy environment."* – Participant 05, Line 42	45
Engineering Shop- Tools and Equipment	***Count***
"The student [Engineering Shop] is more like a machining shop. There are welders, A CNC mill, sheet metal planers, a Radial press, band saws and tube benders." -Participant 10, Line 69 *"The student [Engineering Shop]is much bigger, has more equipment, and the machines are used more for bigger material and can cut pretty much any kind of metal, it feels more like a workshop than a lab…".* – Participant 12, Line 80	26

B. Theme 2: Saftey and Access

The second distinction students recognized between the two spaces were differences in safety and access issues. In the engineering shop, students found larger and potentially more dangerous equipment requiring stricter safety expectations and limited use. Students especially emphasized the access limitations, as many were interested in the equipment in the engineering shop, but access to this space is limited to seniors and specific types of engineering projects. Many students noted the frustration to not having this type of space accessible to them earlier in their engineering coursework. Some representative quotes for this theme can be found in Table 2.

TABLE II. SAFETY AND ACCESS QUOTE EXAMPLES STUDENTS PERCEIVED IN MAKERSPACES AND ENGINEERING SHOPS

Student Quote Examples about Safety and Access	
Makerspace – Safety	***Frequency Count***
"To go in, you need closed toe shoes and to use the machines you need safety glasses." - Participant 32, Line 191 *"The labs also have some common-sense rules, like no eating or drinking around equipment."* – Participant 32, Line 198	14
Makerspace - Access	***Count***
"[Makerspace] seemed more interesting and useful to me because as a Freshman I can use it and there are specific people there to help me" – Participant 2, Line 16 *"Students are encouraged to bring their own project ideas to this lab, whether it be a senior design or something just for fun. All of the equipment here is first come first serve."* – Participant 27, Line 166	19
Engineering Shop - Safety	***Count***
"All of the machines are out in the open and there use puts the user and others at risk of injury, cuts, burns, chemical exposure, etc. Because of this there are a lot more policies to be followed to keep everyone safe. Safety glasses must be worn everywhere at all times. And each machine has its own protocol of safety procedures." – Participant 4, Line 26 *"The equipment can be dangerous, so safety is a huge part of their policy. Students must sign a consent form in case of any injury."* – Participant 26, Line 157	16
Engineering Shop - Access	***Count***
"The [Engineering Shop] is more advanced and hands on which is partially why it's only available to senior students." – Participant 8, Line 58 *"In the prototyping lab you can't work on personal projects so that makes it rather useless to me personally."* – Participant 15, Line 96 *"The prototyping lab is restricted to school projects only, with MAE projects taking up the bulk of the use…".* – Participant 17, Line 104	29

V. DISCUSSION AND IMPLICATIONS

This study illustrates the differences in students' initial impressions of a traditional engineering shop and a contemporary makerspace. Our preliminary findings suggest that students identify the contemporary makerspace as a place to support collaboration and innovative design. In addition, students perceived the tools and equipment in the makerspaces as being newer technology, which utilize computerized processes. In contrast, students viewed the equipment in the engineering shop to be more traditional for the use of wood and metalworking and identified the engineering shop as a place to understand larger scale production and manufacturing processes. These perceptions are consistent with the characterization of these spaces found in literature [15], [16], [17] and what individuals in the engineering field might expect. However, it is important to recognize and evaluate how students' perceptions of these spaces might influence their perceived interest and value in the utilization of each space, in particular with relationship to each spaces safety and access requirements.

A prominent theme in student responses was their interest in getting more involved in the student prototyping lab, but not having the ability to access the space until late in their engineering coursework. Based on our preliminary findings, the authors speculate that makerspaces may create an environment that can help first, and second year engineering students engage in the development of the skills and knowledge needed to be prepared for careers in engineering. Additionally, students are interested in getting involved in a traditional engineering shop earlier in their undergraduate experiences. This may suggest a need for engineering departments to carefully evaluate safety and access considerations for an on-campus spaces for making to ensure that early year undergraduates have access and training available over a range of spaces.

VI. IMPLICATIONS FOR PRACTICE AND FUTURE WORK

This study provides a preliminary investigation into students' impression of differences between two on-campus spaces for making. This exploratory study may help university-affiliated makerspaces to better define the use and accessibility of their spaces to enhance and promote engineering education formation. However, we recognize that this work is constrained to student perceptions of two spaces at a single institution. To increase the generalizability of this work we hope to investigate additional stakeholder perceptions (faculty and staff) at a variety of institutions while at the same time further developing our investigational methodologies. We anticipate that the continuation of these studies may provide future direction for engineering departments' development of campus spaces for making.

VII. ACKNOWLEDGEMENTS

This material is based upon work supported in part by the National Science Foundation (NSF) No. EEC- 1664272. Any opinions, findings and conclusions or recommendations expressed in this material do not necessarily reflect those of NSF.

VIII. References

[1] L. Martin, “The Promise of the Maker Movement for Education,” *J. Pre-College Eng. Educ. Res. J. Pre-College Eng. Educ. Res. J. Pre-College Eng. Educ. Res.*, vol. 5, no. 5, pp. 1–30, 2015.

[2] A. Wigner, M. Lande, and S. S. Jordan, “How Can Maker Skills Fit in with Accreditation Demands for Undergraduate Engineering Programs?,” *Am. Soc. Eng. Educ.*, 2016.

[3] J. E. Froyd, P. C. Wankat, and K. A. Smith, “Five major shifts in 100 years of engineering education,” *Proc. IEEE*, vol. 100, no. SPL CONTENT, pp. 1344–1360, 2012.

[4] T. W. Barrett, M. C. Pizzico, B. Levy, and R. L. Nagel, “A Review of University Maker Spaces A Review of University Maker Spaces Introduction,” *122nd ASEE Annu. Conf. Expo.*, pp. 1–16, Jun. 2015.

[5] A. Longo, B. Yoder, R. C. C. Guerra, and R. Tsanov, “University Makerspaces: Characteristics and Impact on Student Success in Engineering and Engineering Technology Education,” *ASEE Annu. Conf. Expo.*, pp. 1–19, 2017.

[6] A. W. Epstein, S. Rudolph, H. H. Einstein, and P. M. Reis, “Enhancing Design Students’ Comfort and Versatility in the Shop: A Project-Based Approach,” *2014 Asee Annu. Conf.*, no. July 2010, 2014.

[7] N. Gershenfeld, “How to Make Almost Anything: The Digital Fabrication Revolution,” *Foreign Aff. VO - 91*, no. 6, p. 43, 2012.

[8] K. Sheridan, E. R. Halverson, B. Litts, L. Brahms, L. Jacobs-Priebe, and T. Owens, “Learning in the Making: A Comparative Case Study of Three Makerspaces,” *Harv. Educ. Rev.*, vol. 84, no. 4, pp. 505–532, 2014.S.

[9] L. Martinez and G. Stager, *Invent to learn : making, tinkering, and engineering in the classroom*. Torrance: Constructing Modern Knowledge Press, 2013

[10] G. L. Downey et al., “The Globally Competent Engineer: Working Effectively with People Who Define Problems Differently,” J. Eng. Educ., vol. 95, no. 2, pp. 107–122, Apr. 2006.

[11] E. R. Halverson and K. Sheridan, “The Maker Movement in Education,” *Harv. Educ. Rev.*, vol. 84, no. 4, pp. 495–504, 2014.

[12] Y.-C. Hsu, S. Baldwin, and Y.-H. Ching, “Learning through Making and Maker Education,” *TechTrends*, 2017.

[13] D. Baker, S. Krause, and S. Y. Purzer, “Developing an instrument to measure tinkering and technical self-efficacy in engineering,” *Am. Soc. Eng. Educ. Conf.*, 2008.

[14] B. E. Seely, “The Other Re-engineering of Engineering Education, 1900-1965,” *J. Eng. Educ.*, vol. 88, no. 3, pp. 285–294, 1999.

[15] R. H. Todd, W. E. Red, S. P. Magleby, and S. Coe, “Manufacturing: a strategic opportunity for engineering education,” *J. Eng. Educ.*, vol. 90, no. July, pp. 397–405, 2001.

[16] M. E. Ssemakula, “Ensuring Safe Use of the Machine Shop by Students,” *122nd ASEE Annu. Conf. Expo.*, 2015.

[17] D. M. Malicky, J. G. Kohl, and M. Z. Huang, “Integrating a Machine Shop Class into the Mechanical Engineering Curriculum: Experiential and Inductive Learning,” *Int. J. Mech. Eng. Educ.*, vol. 38, no. 2, pp. 135–146, 2010.