Promising Practices to Support Class Projects That Incorporate the Use of an Academic Makerspace 6th International Symposium on Academic Makerspaces

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Audrey R. Boklage [1] and Roxana Carbonell [2]

[1]A. Boklage; Dept. of Mechanical Eng., University of Texas at Austin; e-mail: Audrey.boklge@austin.utexas.edu

[2]Roxana Carbonell; Dept. of Mechanical Eng., University of Texas at Austin; e-mail: roxy.carbonell@austin.utexas.edu

Introduction

In the past decade, education researchers have been diving into the *what* of university makerspaces. This includes the types of machines in the space, the lay out of the space, the materials students are using, and how many people are moving in and out of the spaces [1-4] . Recently, research has begun exploring *what* students are doing in these spaces including the types of projects they are working on [5-7]. Other recent research has explored *who* is in these spaces from staffing to students to faculty [8]. Very recently, education researchers have been asking *why* students are using the space [7, 9, 10]. Sometimes this is out of genuine curiosity and other times it is because students are required to enter the space for a class project. This research integrates the *what, who, and why* of course projects at a university makerspace from the perspective of student and faculty experiences. The results of this investigation are an identification of promising practices to support class projects in undergraduate engineering courses that incorporate the use of a university makerspace.

Methods

Theoretical Framework

When university makerspaces are incorporated into STEM learning environments, it is important to identify promising pedagogical practices within a makerspace. This study will use a theoretical framework established by the Authors that explores promising rather than best practices as promising practices allow readers to consider the specific context of their work and makerspace and find inspiration in these practices. This framework provides an opportunity to bridge what has already been learned through the extensive work on incorporating class projects that utilize a makerspace with the practice of implementing these projects in a university makerspace.

A. *Context*

The study was conducted at a large, public university in the southwestern United States. The university is home to a large engineering school that enrolls approximately 6,000 undergraduate students. The school of engineering is home to a 30,000 square feet makerspaces that is available to all engineering students and faculty for coursework, research, and both class and personal projects. This space includes machines such as desktop additive manufacturing machines (3D printers), laser cutters, soldering stations, desktop CNCs, and a variety of hand tools. Three university full time employees lead the space with a staff of 30 undergraduate student workers. One of the missions of the space is to encourage students to engage in design projects. To do this, faculty have the opportunity to apply for and receive a makerspace project grant. This grant is given to select engineering professors at the beginning of each semester. The funding is often necessary for professors to explore the space and create opportunities for their students to engage in projects that deviate from the standard pencil to paper design of traditional engineering coursework [6].

B. *Research Design*

This investigation used an instrumental, multiple case study design, consisting of six professors, seven course, and 9 class projects. Each course and project served as a bounded context within the semesters they were implemented (Fall of 2018- Spring 2020). The participant interviews served as our units of analysis. These bounded systems swerved the what of our research, as we were interested in the student and faculty experiences during a semester long class project that used the university makerspace. Researcher recruited faculty participants who were awarded a makerspace project grant at the beginning of Fall and Spring Semesters. Students were recruited by the researchers after a brief presentation of the study in the classroom of the engineering course that was incorporating the use of the makerspaces. These presentations were less than 5 minutes in length and ended with researchers sharing their email with the class and students emailing researchers if they were interested in participating. Student participants received a $25 dollar gift card to an online retailer for their participation in an interview.

This study used semi-structured interviews during the semester of the course project. These interviews were chosen because of their ability to ask questions about specific details of the project as well as follow-up questions [11]. The purpose of the interviews was to understand the context of each project as well as faculty and student perspectives on the planning, implementation, and reflections of the course projects. These interviews ranged in time from 20 to 60 minutes in length and were digitally recorded and transcribed. Additionally, artifacts, in the form of course syllabi and images of the physical projects students created, were collected with the purpose of supporting emergent findings of the study.

Data collection and analysis occurred over the course of 18 months. The primary source of data, the semi-structured interview transcripts, were analyzed first. This included transcribing interviews verbatim within 24 hours after conducting the interview. This allowed researchers an opportunity to reflect and begin noting questions or comments that emerged from this phase of analysis. Artifacts were collected, organized and redacted as well. Subsequent analysis of the interviews took place in three phases. In phase one, researcher individually open coded the interviews. During phase two, researchers entered a phase of focused coding which enabled the process of memo writing. It was at this point in analysis, researchers began making comparisons between data, codes and categories [12]. As codes came in tandem with the memo-ing process, researchers entered the third stage of analysis in which the data was then organized into nine themes that answered our research question.

Results

Researchers conducted six semi-structured interviews with professors of undergraduate engineering. These professors were selected from a group of grant recipients who received university funding to develop a project that incorporated the university makerspace. Of these professors, three had students who volunteered to be interviewed about their experiences in the makerspace. Direct participant quotes are indicated by italics throughout the manuscript and all participant names are pseudonyms.

Each grant recipient used a variety of promising practices; for example, some of the professors incorporated multiple projects into one course. Two professors had extensive backgrounds in implementing makerspace projects while the remaining four had minimal or no prior experience with the space. Due to the differences of these professors' makerspace experiences and pedagogy, this manuscript also includes information about relevant experience outside of the specific grant-based project. The stories of these professors and their students' experiences illuminate several promising practices for the implementation and support of makerspace-based projects in undergraduate engineering classrooms. The following discussion includes nine themes as a result of the aforementioned qualitative data analysis.

Discussion

Encourage accessible and affordable prototyping through makerspace use to promote better finished projects

As a professor who works with both the makerspace and machine shop regularly, Dr. Carpenter has seen the makerspace impact the accessibility of prototyping for his students. The primary outcome that he identifies is an increase in working final projects. Our findings recognize that the makerspace gives students an opportunity to use more affordable materials and identify important aspects of their design before approaching more expensive methods of making, either in the machine shop or with higher resolution materials in the makerspace. This iteration can be encouraged in different projects and makerspace models by starting encouraging students to start with scrap materials, cardboard, or simplified models.

Create challenging requirements while still encouraging tinkering and trial and error as necessary parts of the process

When students are well acquainted with the makerspace, more challenging projects are possible. Dr. Carpenter saw that over time as he began having students who had access to a makerspace throughout their undergraduate experience, he was able to create more challenging projects that incorporated higher standards of engineering concepts. But due to manufacturing issues that students did not expect, encouraging some tinkering and trial and error was an integral part of these engineering practices. Dr. Smith found that her students were so excited about their projects that they actually held themselves to a more rigid standard (e.g., iterating on their puzzle pieces until they fit together).

Include components of the assignment outside of the engineering skillset such as record keeping, group dynamics, and time management

Dr. Carpenter identified these soft skills as important elements of successfully completing a makerspace-based project and also noted that these skills are extremely outside of the engineering context. Regardless of students' future career paths, these important skills can be incorporated into the engineering curriculum through a makerspace.

Create enjoyable end of semester celebrations that allow students to show off their final projects

Both Dr. Mills and Dr. Carpenter recognize the importance of celebrating student's makerspace projects. Dr. Mills senior design students shared their projects in a large "expo" at the end of the year. This expo is held the highly visible location of the lobby of the same building as the makerspace. In the two projects Dr. Carpenter discussed, he shared the importance of integrating a public and enjoyable (e.g., dropping water on the head of your professor, racing cars in an atrium) final project demonstration. These events provide opportunities for students to celebrate the end of the semester during the sometimes stressful finals week.

Encourages students to use the makerspace earlier in their academic career and/or during their coursework. Support this use with scaffolded support

Both Dr. Smith and Dr. Mills designed methods to introduce students with minimal prior experience with making, or the makerspace to the makerspace. For Dr. Smith, this process was done over the course of a semester, as she began with a project that was low stakes. This straight-forward 3D puzzle project allowed students to explore the makerspace in a low-pressure project during the first weeks of the semester. In order to support this project, Dr. Smith beta-tested her own project during the summer before her course. She explored the feasibility of a project and this helped her guarantee that this assignment served as a positive introduction to the makerspace. Through this beta testing experience, Dr. Smith recognized that students needed to obtain the necessary certifications and gain the skills they would need for a later project. In this case students were required to learn how to solder early in the semester in order to build the sensors for their final project. Dr. Cook approached this in a similar way, when designing benchmarks for her students, one of the earliest benchmarks was to go to the makerspace and get certified on one of the machines. This scaffolding helped ensure that students used the space early in the course. One student, Chip, created his sensor housings and hardware and took continued working on it beyond the project requirements. He and his partner decided, because of their experience 3D printing, to add a compartment for additional supplies that the user of their hardware might need and made the compartment adjustable and collapsible.

Dr. Mills scaffolds the making experience over the course of an entire college career where, ideally freshmen get in the maker studio and start tinkering, moving up an experiential ladder, he aims to have students using the space to solve engineering problems by the middle of their college careers, with the final goal of having students innovating and creating ventures by the end of their undergraduate careers. His freshman course and senior course are targeted towards the first and last stages of this process.

Encourage student interaction with the physical objects

Interaction with physical prototypes is something professors and students identified as an important experience in their makerspace projects. Whether these are students in Dr. Carpenter's class testing and demonstrating their projects or in Dr. Cook's class using models they created, it is clear that physical interaction seems is a beneficial component of makerspace projects. Coming from industry, Dr. Mills recognized the importance of students touching the components and products they were making to be key to fully understanding a product. In his mind, this is the most exciting part of the makerspace and the most useful to student development. Dr. Knight's students all enjoyed finally seeing a physical model of the systems they'd been solving all semester in action. Both Dr. Smith and her students expressed the excitement of designing something digitally and then getting to hold it in their hands after 3D printing. This element of the makerspace not only helps students learn about engineering, but it also creates and supports a sense of enthusiasm about their work.

Allow students to be creative in the making process, this can include open ended projects or open-ended design requirements

Dr. Cook emphasized creativity as a key part of her students' projects, because her project expectations were flexible, students were creative in how they demonstrated different concepts. This included incorporating high resolution prototyping materials along with low-resolution materials including straws, rubber bands, and pipe-cleaners. This freedom provided an opportunity for students to use materials that best demonstrated the concept they were interested in. Dr. Smith gave her student's creative freedom in the puzzle project. Students had the freedom to make something in their comfort zone as they approached the space for the first time or create something that excited them. For example, Joe made a mascot of his favorite band.

Interact with other professors and makerspace staff

Many professors discussed the importance of interactions with the makerspace staff and a desire to establish and maintain a strong ecosystem of support in the makerspace. Dr. Carpenter is experienced with the space but makes a point of going to talk to the makerspace staff to hear about new tools and capabilities. This way he hopes he can keep his students informed about new manufacturing opportunities for their projects. Dr. Smith was unfamiliar with the makerspace at the beginning of her project, and like other first time makerspace users spoke to the staff as a resource for the space. Dr. Wang found it helpful to discuss his project with other faculty who received a makerspace grant and felt that this assisted him in recognizing the potential of integrating the space into his course.

Create projects that students enjoy, especially those who are new to the making experience

Professors who have conducted many projects in the makerspace and those who were new to the space had common ground when it came to finding ways to make projects enjoyable to students. Students in Dr. Smith's class enjoyed their makerspace projects so much that they had already informed their peers, who would be taking the course the following semester, that the class was "*fun",* and they are looking forward to seeing their projects. This idea of fun came up with students and professors as something that was critical to their experiences in the makerspace. While it is not a frequent topic of discussion in undergraduate STEM education this notion of is important, as enjoyment is closely linked to motivation which is known to support engagement, persistence, and learning outcomes [13].

Conclusion

This study contributes to the existing literature about integrating projects that utilize a makerspace into STEM curricula in that it provides promising practices related to faculty professional development and support for how to use and teach in makerspaces. Previous research has found that faculty have scaffolded this makerspace support through a "learn by doing" approach [14]. This research integrates the *what, who, and why* of course projects at a university makerspace from the perspective of student and faculty experiences. While our findings recognize that scaffolding is important to navigate the complexity of makerspace projects, it also provides insight into how to structure and support environments where students can fail-forward, engage with STEM content, and enjoy themselves. Additionally, our findings provide specific insight into what interdisciplinary collaborations and communities look like for both students and faculty. This study builds on the blueprint of promising practices for promoting inclusive makerspaces [15] and provides both faculty and student perspectives of what other promising practices look like in the context of a university makerspace. Finally, these promising practices provide opportunities for students to engage in a space where they can express and grow their STEM identity. Given that identity is closely linked to a sense of belonging, supporting these spaces can contribute to student persistence through a STEM major. This research did not collect demographic data from faculty or students, which is a limitation of this study. Future research should examine these promising practices elucidated from students and faculty using a critical theoretical framework to avoid the reproduction of disparities amongst historically and structurally marginalized students in STEM spaces. Other future work should be conducted to examine the integration of the makerspaces in engineering projects in contexts outside of one university, as this is also limitation of this project. Finally, additional research should examine more in-depth student experiences across the course of a semester or undergraduate career to explore the impact of a makerspace within and outside of a single engineering course.

References

[1] S. R. Kurti, D. Kurti, and L. Fleming, "The Environment and Tools of Great Educational Makerspaces," *Teacher Librarian,* vol. 42, no. 1, pp. 8-12, 2014.

[2] K. Sheriden, E. R. Halverson, B. Litts, L. Brahms, L. Jacobs-Priebe, and T. Owens, "Learning in the Making: A Comparative Case Study of Three Makerspaces," *Harvard Educational Review,* vol. 84, no. 4, pp. 505-531, 2014.

[3] M. Davenport, "Makerspaces: A Practical Guide for Librarians," *Journal of the Medical Library Association,* vol. 103, no. 4, 2015.

[4] S. Farritor, "University-based Makerspaces: A source of innovation," *Technology and Innovation,* vol. 19, no. 1, pp. 389-395, 2017.

[5] B. O'Connell, "Going from curious to maker: New user experiences in a university makerspace," in VentureWell. Proceedings of Open, the Annual Conference, 2015: National Collegiate Inventors & Innovators Alliance, p. 1.

[6] R. Carbonell, A. Boklage, and M. Andrews, "Making Improvements: Pedagogical Iterations of Designing a Class Project in a Makerspace," *Journal of Higher Education Theory and Practice,* vol. 20, no. 13, pp. 194-206, 2020.

[7] L. S. Nadelson *et al.*, "Student Perceptions of and Learning in Makerspaces Embedded in their Undergraduate Engineering Preparation Programs," presented at the American Society of Engineering Education, Virtual, 2020.

[8] T. L. Spencer, V. Spencer, P. B. Patel, and A. S. Jariwala, "Safety in a Student-Run Makerspace via Peer-to-Peer Adaptive Training," presented at the International Symposium on Academic Makerspaces, Cambridge, MA, 2016.

[9] M. Josiam, A. D. Patrick, M. E. Andrews, and M. Borrego, "Makerspace participation: Which students visit, return, and why?," presented at the American Society for Engineering Education, Tampa, FL, 2019.

[10] E. Hilton, M. Tomko, W. C. Newstetter, R. L. Nagel, and J.S. Linsey"Investigating Why Students Choose to Become Involved in a University Makerspace through a Mixed-Methods Study," in American Society of Engineering Education, Salt Lake City, UT, 2018.

[11] G. Thomas, "A typology for the case study in social science following a review of definition, discourse, and structure," *Qualitative inquiry,* vol. 17, no. 6, pp. 511-521, 2011.

[12] B. G. Glaser and A. Strauss, "L.(1967). The discovery of grounded theory: Strategies for qualitative research," *Chicago: Aldine,* 1967.

[13] P. R. Pintrich, "A Motivational Science Perpsective on the Role of Student Motivation in Learning and Teaching Contexts," *Journal of Educational Psychology,* vol. 95, no. 4, pp. 667-686, 2003.

[14] C. Lenhart, J. Bouwma-Gearhart, I. Villanueva, K. Youmans, and L. S. Nadelson, "Engineering Faculty Members' Perceptions of University Makerspaces: Potential Affordances for Curriculum, Instructional Practices, and Student Learning," *International Journal of Engineering Education,* vol. 36, no. 4, pp. 1196-1207, 2020.

[15] N. Kellam, A. Boklage, B. Coley, and Y. Llu, "Promising practices that promote inclusivity at University-affiliated makerspaces within schools of engineering," presented at the Collaborative Network for Engineering and Computing Diversity, Virtual, 2021.