Making Spaces to Supporting Formal, Informal, and Nonformal Learning Spanning a University's Makerspace Learning Ecology
6th International Symposium on Academic Makerspaces

ISAM 2022 Poster No.: 142

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Introduction

The purpose of this cross-case case study project [1] is to ascribe characteristics of differently oriented makerspaces across the learning ecology [2] at a singular institution. By viewing specific spaces that emphasize a range of formal, informal, and nonformal learning contexts, we highlight considerations for physical, social, and cultural contexts, as well as founding design principles, metrics for success, and scalability and sustainability. With being an otherwise homogeneous corpus, this work can highlight the similarities and differences for makerspaces in educational settings.

With the introduction and ongoing incorporation of principles from the Making Community, engineering colleges have begun modifying existing project spaces and creating new makerspaces to reflect this change in mindset. However, the ongoing initiatives to reflect the more creative and less rigidly designed nature of making can be challenging to implement since many ideas are counterintuitive to existing organizational structures. This is especially true in engineering-focused entities where the parties that have historically managed existing workspaces and their resources may not be as familiar with the pedological approaches and philosophies behind these areas [3]. In addition, by the very nature of making, many common trends in makerspaces present unique challenges for the management; They require a very abstract look at the purposes and function in the settings they will operate inside.

Across One University: 3 Settings

Within a STEM-focused undergraduate school, we identify multiple workspaces available to students that provide aspects of makerspaces. The school is focused on the application of STEM learning through hands-on learning, design and project-based learning.

A. *Library Makerspace as a Starting Point for All*

A newly developed Library Makerspace is being installed this academic year as part of a series of initiatives in the newly renovated library space. This space is special in that it lacks a disciplinary basis and is presented as a space for all students to use, both for academic endeavors and also for fun, personal projects. It is managed and run by student life and engagement, primarily as an additional space that can provide personal and professional development for students. This space represents a new, intentionally built makerspace that has not yet developed a community of practice surrounding it.

B. *Machine Shop Area for Mechanical Engineering Majors*

The established traditional machine shops and 3D Printing labs that are run by the Mechanical Engineering department of the school demonstrate a classical approach to running fabrication spaces, with abundant resources available. A fist-year engineering course serves as a formal introduction to the space, with CAD and a team-based fabrication design project serving as its foundation. Safety and professional practice are an explicit set of learning goals.

C. *Lab Space to Support Low- and High-Fidelity Prototyping*

Another space to be examined is a product design and development lab. This space is funded by the Mechanical Engineering department but is run by staff involved in the Maker Community and familiar with its concepts and approaches. This space demonstrates a classic idea of a makerspace and is the best comparison to classical makerspaces outside of higher education. Tools like a laser cutter, 3D printers, as well as low-fidelity prototyping materials are made available to student to support their course projects as well as student engineering competition teams.

Examination of Maker Values in the Designated Spaces

In these three spaces, there are many comparisons to be drawn between them, but most notably can act as microcosms of different approaches taken inside of higher education regarding the implementation of Making principles into workspaces and their learning experiences for students. Using the principles developed previously [3], a broad view analysis can be performed of each space. The machine shop and 3D print lab possess attributes of Practical Ingenuity [4, 5], Personal Invention, and Community Building through a peer mentorship support system. Students are encouraged to bring in their own projects, which are inspected by certain management personnel before being approved. Students then work with a mentor to produce their projects and have the opportunity eventually to work in the spaces given enough time and experience in the labs. The library, on the other hand, presents as a new, relatively undeveloped area. While the previously discussed labs have a strict hierarchy and approach to be followed, the library makerspace is a newly developed area that doesn't have a pre-existing organizational structure. In the current development life of the area, it is supposed to encourage values of *Practical Ingenuity*, *Personal Investment*, *Playful Invention*, *Community Building*, and Self-*Directed Learning*. However, the support of these values hasn't yet been solidified since there are still challenges in the startup of the space. Lastly, the existing lab system recently upgraded for their work. It is run by individuals who have been extensively educated on maker pedological approaches and represents the seven ideal values of a maker-based learning experience. However, the support is much more limited due to a specific focus on supporting specific classes.

Materials, Methods, and Analysis

To discuss each space in more detail and perform a qualitive analysis into how the motivations and constraints of each space effects its ability to encourage Maker-Based Learning, a systematic approach will be taken to examining each space. Each space will be researched and examined in 4 ways, to allow more direct comparisons to be drawn, and more detailed information to be available. First, a look into the organization(s) running the space will be done. Questions involving the purpose of the organization, their fiscal and educational limitations, and their perceived goal with the space will be inspected. Next, a look into the management structure of the spaces will be done. Here, the more nuanced elements of how the spaces are ran and funded will be detailed. This should give more of a practical understanding of how the spaces are truly to be ran, rather than the ideal operating conditions the owning organization operates within, can be available for a contrast between theoretical and applied support of these makerspaces. Next, the actual workspaces and resources will be inspected. How was equipment selected, how does it support the education, and how its operation effects the learning experiences will be the focus of this level of analysis. Lastly, a broader view with the previously investigated information will be taken to determine the actual motivations and limitations of the space. This large view of how the space functions as a Makerspace or lab should be invaluable to direct comparisons between the spaces.

Discussion

This leads to the discussion of results, where the individual spaces can be used to model larger contexts and situations that makerspaces in higher education may face. How does the ownership effect a makerspace? Does having fab. lab run by a specific group effect how the space grows and the culture? How does a rigid management style effect students' participation and personal investment into Making? Does a lack of definition lead to a lack of direction for a space? How does the restrictions and real-world considerations effect the culture of a space? This larger investigation should provide important context into how different factors impact a making experience.

Acknowledgement

This material is based upon work supported by the National Science Foundation under Grant No. 2010696.

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