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Board 398: The Effects of COVID-19 on Students' Tool Usage in Academic Makerspaces

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The Effects of COVID-19 on Students' Tool Usage in Academic Makerspaces

Abstract

When college campuses resumed in-person learning opportunities following initial lockdowns during the COVID-19 pandemic, many facets of campus life looked different. These differences continue to evolve semester to semester because of changing health guidelines, school decisions, and personal convictions. Academic makerspaces were not exempt from these changes and have experienced fluctuating usage and usage barriers over the past several semesters. Better understanding the effects of COVID-19 on academic makerspaces can help ensure that students continue to draw maximum benefits from these learning spaces and also provides potential advice for administrator and educators for future disturbances. Data collected via tool usage surveys administered to makerspace users at a large public university during the three semesters following the start of the pandemic (Fall 2020, Spring 2021, and Spring 2022) is used here to investigate. COVID-19 restrictions present during Fall 2020 and Spring 2021 were mostly loosened in Spring 2022. The makerspace is modeled as a bipartite network, with student and tool interactions determined via end-of-semester surveys. The network is analyzed using nestedness, a metric primarily used in ecology to evaluate the stability of an ecosystem and proposed here as a quantitative method to evaluate makerspace health. The surveys used to create the network models also provide validation, as students were asked to share tools used during the semester in question. The results suggest that nestedness is linearly proportional to usage, both increases and decreases. As such, tracking the nestedness of a makespace over time can serve as a warning that unintended restrictions are in place, intentional restrictions and/or policies may be too severe, or whether a space has effectively recovered from temporary restrictions.

Introduction and Background

Engineering makerspaces in academic settings are becoming significantly more common as research continues to hail their benefits for engineering education [1-4]. Network modeling of the spaces have successfully identified critical tools within the space, however the effects of large-scale events affecting usage over time has not yet been explored[4]. The importance of these spaces for enhancing the education of engineering students makes understanding the impact of intended and unintended restrictions critical, for example hidden roadblocks that present challenges specifically for minority students [1, 5, 6]. The COVID-19 pandemic presents a unique opportunity to understand the impact on longer term student-use dynamics caused by intended restrictions. Methods to identify when a space is not performing as intended can aid makerspace administrators in making changes to facilitate a more inclusive and effective space.

To Network modeling and analysis techniques from ecology are used here to evaluate how makerspaces changed during and after COVID-19 restrictions [4, 7, 8]. The ecological approach is used due to similarities in network characteristics between the bipartite nature of makerspaces (interactions between students and tools) and mutually beneficial networks in nature (such as plant-pollinator networks) [9] . The ecological metrics nestedness and connectance, which are associated with these types of ecological networks, are tested here for their ability to evaluate and quantify *if* and *how much* a makerspace network has changed over time. Nestedness and connectance are utilized in tandem with survey data to evaluate makerspace health and quantify makerspace performance [10-12]. Comparisons between semesters with COVID-19 usage restrictions and without (operations returned to semi-normalcy) provide a dynamic view of an academic makerspace with and recovering from intentional usage restrictions.

Methods

Data Collection

An engineering makerspace at a large public university in the southern United States serves as the case study. The makerspace is staff run with some student workers who carry out build request. The primary goal of the space is to support engineering courses. No personal usage is allowed by students and some organizations can use the space for a fee. The space has some tools that are request only, where students submit a request for fabrication of their part.

End of semester tool usage surveys were collected across three semesters: Fall 2020, Spring 2021, and Spring 2022. Survey participants were recruited first by emailing students in classes that use the makerspace and then by emailing a master list of students who used the space that semester. The survey was designed to take approximately 15 minutes to complete and consisted of 50 questions that asked about tool usage, prior makerspace involvement, and student demographics. Students were given a $20 gift card for completing the survey. The Fall 2020 survey asked students to indicate the tools they used, while the Spring 2021 and Spring 2022 surveys also inquired about the frequency with which tools were used. Minor edits to the questions and tools listed were made between semesters.

The processed survey data found some entries from students who did not complete the entire survey or who indicated that they did not use any tools in the space. These were omitted from the analysis. This left 54 students for Fall 2020, 178 students for Spring 2021, and 77 students for Spring 2022.

Network Model Creation

The bipartite network models were generated from the student's self-reported tool usage during each semester [4, 13]. An example bipartite makerspace network is shown in Figure 1a and its graph depiction is shown in Figure 1b. A structural matrix (an example shown in Figure 1c) was then created for the network, with a F_{ij} entry of one indicating tool j was used by student i and a zero indicating student i didn't use tool j.

Nestedness

Analyzing a network's nestedness requires rearranging the network's matrix (Figure 1c) in order of most "generalist" student and tool at the top-left and most "specialist" student and tool at the bottom-left/top-right respectively, creating a triangular structure [10, 11]. The calculation of nestedness provides a value between zero and one, with one being perfectly nested (Figure 1 in an example of a perfectly nested bipartite network) and zero being perfectly un-nested or random. The calculation of nestedness was done using MATLAB [14] and is abbreviatedly clarified with Eqs. 1 and 2 (more details can be found here [15-17]) with M_{ij} as the nestedness of the row, n_{ij} the number of ones that match between row *i* and *j*, and k_j and k_i the number of one's in row *j* and *i* respectively. This process is conducted for all row pairs and the final nestedness or NODF values for the rows is calculated. The same process is then followed for all the columns. Equation 2 normalizes these row/column values to provide the nestedness of the overall network as a value from zero to one (NODF) [14].

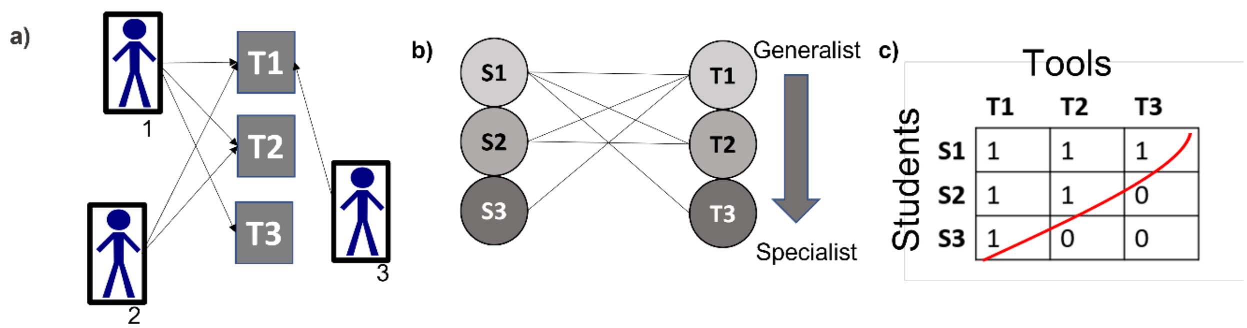

Figure 1: (a) A hypothetical makerspace (3 students and 3 tools) with a highly nested structure is shown as (b) bipartite graph organized with most general (connected) students and tools at the top and the most specialized at the bottom and (c) the network's structural matrix, organized to highlight the nested structure (noted by the red curve) with most connected students/tools at the top-left and least connected bottom-left/top-right.

$$M_{ij} = \begin{cases} 0 \ if \ c \leq k_j \\ \frac{n_{ij}}{\min(k_i, k_j)} \ Otherwise \end{cases} \tag{1}$$

$$N_{NODF} = \frac{\sum_{ij} M_{ij} row + \sum_{ij} M_{ij} col}{\frac{m(m-1)}{2} + \frac{n(n-1)}{2}} \tag{2}$$

Connectance

The network metric connectance (Eq. 3) quantitatively relates the number of connections in a network (*L*) to total possible number of connections for a network with a given number of rows (N_{rows}) and columns ($N_{columns}$). The connectance of a makerspace provides a rapid view of how many tools students are using, the higher the connectance the more tools students are using.

$$C = \frac{L}{N_{rows} N_{columns}} \tag{3}$$

Results

Student Self-Reported Usage (Surveys)

Figure 2 shows the percentage of students surveyed each semester that indicated they used tools falling into 12 general groups. A small dip is seen from Fall 2020 to Spring 2021 followed by a large increase from Spring 2021 to Spring 2022 across almost all tool categories. The dip between Fall 2020 and Spring 2021 is interesting given that COVID restrictions did not change much, if at all, between these two semesters. A consistent upward trend across all three semesters is seen for metal tools, the work areas, paint booth, and other category.

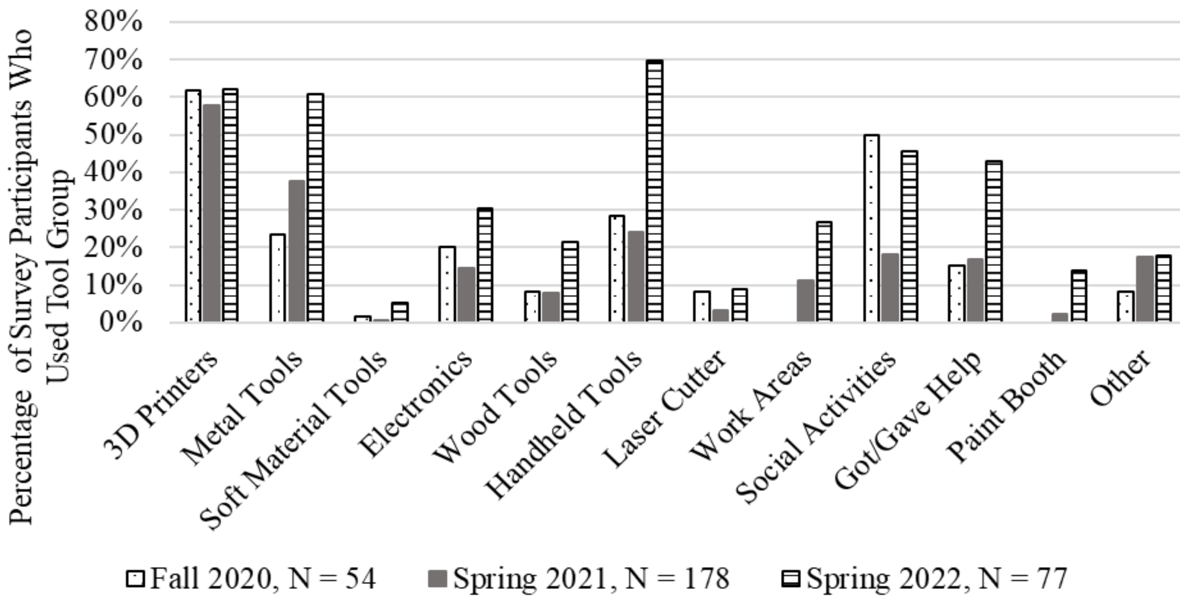

Figure 2: Percentage of students surveyed who indicated using a tool across twelve general tool categories for Fall 2020, Spring 2021, and Spring 2022.

Nestedness

The nestendess and connectance results are summarized in Table 1. The nestedness and connectance values are the highest during the Spring 2022 semester when restrictions were the lowest. The lower values in Fall 2020 and Spring 2021 indicate that the space was not performing for students at its full capability. These results match the general survey findings, with Spring 2022 having the highest percentage of users surveyed using a wider array of tools and a majority of the tool groups seeing lower usage within the survey population in Spring 2021. The lower nestedness values in Fall 2020 and Spring 2021 also indicate that students were likely coming in to only use specific tools, most likely at the direction of their classes. The higher nestedness value for Spring 2022 corresponds to most students (among those surveyed) interacting with the general tools and a few also using more speciliazed tools, suggesting a return to more normal operations.

Table 1: Nestedness and connectance values for the school's general tool network models across three semesters.

Semester/Year	Nestedness	Connectance
Fall 2020	*0.42*	*0.24*
Spring 2021	*0.33*	*0.18*
Spring 2022	*0.55*	*0.34*

Discussion

The negative impacts on usage of the COVID-19 are quantitatively visible via the nestedness and connectance metrics. Figure 2 shows that students who did use the space used more tools overall, possibly due to COVID-19 related restrictions being lifted. The network analysis results provide measurable insight into the current "health" of the makerspace and *why* space may (or may not) be experiencing challenges when coupled with the survey. The network metrics in Table 1 identify that students were using the space in a significantly different pattern during COVID-19 restrictions than during Spring 2022, when a higher connectance and nestedness indicate return to a healthy and robust student usage space. The higher nestedness in the first semester of COVID-19 restrictions (Fall 2020) could indicate the space had some initial resistance to change. The additional drop in nestedness seen in Spring 2021 can also be attributed to students no longer seeking out the space due to restrictions they learned about in Fall 2020.

Conclusions

Those familiar with academic engineering makerspaces are aware that COVID-19 restrictions had a large impact on the tool usage by students. The analysis here is able to quantitatively show how this decline and return visualized itself in terms of the makerspace student-tool network. The COVID-19 pandemic provides a purposeful restriction scenario for makerspaces that supports the use of metrics like nestedness and connectance being used in the future to understand when unintentional restrictions may be stifling usage. Coupled with a traditional survey, quantitative network metrics provide a more in-depth understanding of makerspace functioning.

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