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MEASURING THE HEALTH OF MAKERSPACES DURING LARGE DISRUPTIONS SUCH AS THE COVID-19 PANDEMIC

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ABSTRACT

As the popularity of makerspaces and maker culture has skyrocketed over the past two decades, numerous studies have been conducted to investigate the benefits of makerspaces for university students and how to best establish an inclusive, welcoming environment in these spaces on college campuses. However, unprecedented disruptions, such as the COVID-19 pandemic, have the potential to greatly affect the way that students interact with makerspaces and the benefits that result. In this study, a survey asking about prior makerspace involvement, tool usage, and student demographics was administered to students who use academic makerspaces at two large public universities. Survey data was collected for three semesters (Fall 2020, Spring 2021, and Spring 2022) and spanned both during and after the height of the COVID-19 pandemic. To quantify the differences between the semesters, nestedness and connectance metrics inspired by ecological plant-pollinator networks were utilized. These ecological metrics allow for the structure of the interactions of a network to be measured, with nestedness highlighting how students interact with tools and connectance with the quantity of student-to-tool interaction. The network analysis was used to better gauge the health of the makerspace and the type and frequency of interactions between tools. The raw survey data combined with the ecological metrics provided unique insight into the struggles the makerspaces encountered throughout the pandemic. It was found that nestedness, a measure of system stability, decreases with a decrease in tool usage. Additionally, the higher the connectance the more students interacted with the space. Utilizing metrics such as these and better understanding student tool interactions can aid makerspaces in monitoring their success and maintaining a healthy and welcoming space, as well as tracking the current health of the space. In combination with the survey results, a deep understanding of what challenges the space is facing can be captured.

Keywords: Makerspace, Engineering Education, Network Modeling, Bio-inspired Design

1. Introduction

Makerspaces have been growing significantly through the years, with several benefits highlighted for improving engineering education [1-4]. Research has shown that use of makerspaces increases student's motivation to learn, design self-efficacy, sense of belonging, and future participation in engineering [5-7]. While several key tools and activities have been identified within the space [8, 9], the effects of large-scale events that could affect makerspace usage have not been extensively explored. With makerspaces being highly important to enhancing the education of engineering students as well as the challenges gender, race, and ethnic minority students may face within the space [1, 10-12], understanding the dynamics of what occurs to a space during disruption can be critical. Being able to identify the signs that a space is not performing as intended can aid makerspace representatives to make the necessary changes to facilitate a more inclusive, effective space. The COVID-19 pandemic provided an opportunity to study the effects that large scale disruptive events have on a makerspace and can provide insight as to what occurs to a space where usage is restricted by outside factors. Understanding how a large-scale restriction event affects the makerspace can aid in identifying if there are roadblocks in existing makerspaces.

Network analysis-based ecological metrics are used to evaluate and quantify how *much* the space changed through semesters (i.e., robustness over time). Visualizing a makerspace as a network and utilizing ecological analysis has provided valuable insight into the makerspace [4, 9, 13, 14]. Expanding on this research, two metrics used by ecologists (nestedness and connectance) are utilized in tandem with survey data to evaluate makerspace health and provide a quantifiable way to see how a makerspace is performing [15-18]. These metrics are used in mutualistic networks in nature such as plant-pollinator networks to identify the structure and conditions of the network [18]. Due to the mutually beneficial similarities between the networks, these metrics are extended to the makerspace to quantify the relationships in the space. Comparisons are made between COVID-19 semesters where usage was limited and a post-

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COVID-19 semester where operations returned to semi-normalcy. Nestedness in ecology provides a measure of the structure of the space, with high nestedness networks having "generalist" interacting with "specialist" to generate a robust network resistant to change [15, 16, 18, 19]. On the other hand, connectance can be used in combination with another ecological metric to help aid in understanding the current state of a network as well as the potential indicator to how the network is performing [17, 20]. In the context of the makerspace, nestedness allows for a view of the typical order that tools were used, where students that interact with a wide variety of tools tend to interact with a wide selection of general and specialized tools, and students that do not interact as much with the space primarily interact with the more "general" tools in the space before. Connectance refers to the ratio of actual student-tool interactions to the total possible number of student tool interactions [17, 20]. A higher connectance value indicates a higher overall tool usage in the makerspace. These metrics can be used in combination to provide a quantitative view to how a makerspace is performing.

While the ecological metrics provide a quantifiable metric to evaluate the space, traditional survey techniques provide context to visualize both the demographic changes and individual tool usage differences across semesters. Examples of differences explored include tool usage by general tool category, tool usage by demographic, and tool usage by class participation. The network analysis and in-depth surveys together enable the effects of the COVID-19 pandemic to be analyzed, quantitatively visualizing how the makerspaces behaved because of intentional restrictions. This understanding provides foundational data for an early warning system for and testing preventive measures against unintended restrictions.

2. METHODS

2.1 Data Collection

The makerspace studied is housed in an engineering building at a large public research university in the southwest United States. The makerspace is open for all undergraduate engineering students and primarily serves as a space to help students fabricate parts needed for their courses. While some clubs are permitted to use the space for a fee, students are not allowed to work on any personal projects. Some tools are available for general use, while others require a fabrication request, where a machinist fabricates the part using more advanced machines. The makerspace is run by paid staff, including some students who help carry out the fabrication requests.

An end of semester tool usage survey was used to collect data for Fall 2020, Spring 2021, and Spring 2022. Due to limited funding and minimal change in COVID-19 restrictions, data was not collected in Fall 2021. Students in classes that use the makerspace were recruited first, followed by the full list of students who used the makerspace each semester. The survey contained roughly 50 questions about prior makerspace experience, tool usage, and demographics. The survey took roughly 15 minutes to complete. The Fall 2020 survey asked students which tools they used, while the Spring 2021 and 2022 surveys also asked about how frequently they used tools. Additional small edits to the questions and tools were made from semester to semester.

TABLE 1: SPECIFIC TOOLS AT EACH SPACE ORGANIZED INTO 12 GENERAL TOOL CATEGORIES. *DENOTES TOOL WAS NOT ON THE FALL 2020 SURVEY.

General Tool Category	Specific Tools
3D Printing	Ultimaker, Dremel DigiLab, SLS Formiga, Stratasys, Resin Printers, 3D Scanner, Studio System Printer (Metal), Scanner 3D, Don't Know, Other
Metal Tools	Manual Mill, CNC Mill, Manual Lathe, CNC Lathe*, Waterjet, Drill Press, Bandsaw*, Electric Discharge Machine*, Surface Grinder*, Injection Molder*, Vacuum Former*, Hydraulic Press*, Metal Shears*, Welding Equipment*, Other
Soft Material Tools	Vinyl/Paper Cutter, Foam Cutter, Sewing Machine
Electronics	Circuit Board Plotter*, Multimeter*, Power Supply*, Soldering Equipment*, Oscilloscope*, Logic Analyzer*, Other
Wood Tools	CNC Wood Router, Hand Router*, Drill Press, Table Saw, Miter (Chop) Saw, Hand Sander, Bandsaw*, Belt Sander*, Circular Saw*, Jigsaw*, Vacuum Former*, Other
Handheld Tools	Hammer*, Pliers*, Vice Grips*, Clamp*, Screwdriver*, Hand Drill*, Angle Grinder*, Chisel*, Measure Tape*, Table Vice*, Glue Gun*, Wire Cutters*, Hand Saw*, Dremel*, Tap & Dye*, Scissors*, Tin Snips*, X-ACTO Knife*, Other
Laser Cutter	
Work Areas*	CAD Station*, Construction Station*, Workbench*, Mobile HDTV*, Whiteboard*
Social Activities	Studied, Hung Out, Met with a Group
Help	Helped by another student, Helped by a staff member, Helped someone else
Paint Booth	Paint booth
Other	User Defined

Students were asked to select the *general* tool categories that they used followed by the *specific* tools they used in each selected tool category for the tool usage question. Table 1 shows the general tool categories as well as the corresponding specific tools listed as options. Some general tools such as the laser cutter or paint booth are standalone tools and do not have corresponding specific tools. In these cases, the general tool was used in the specific tool analysis.

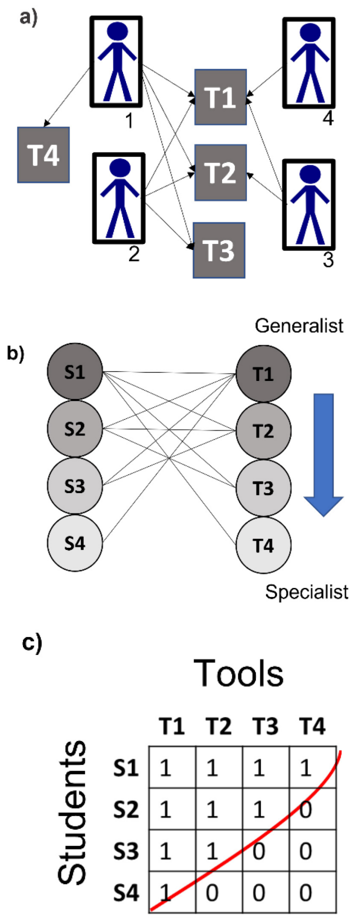

FIGURE 1: A) HIGHLY NESTED SAMPLE MAKERSPACE WITH 3 STUDENTS AND 4 TOOLS, B) THE BIPARTITE NETWORK MODEL ORGANIZED WITH GENERALISTS AT THE TOP AND SPECIALIST AT THE BOTTOM, AND C) TABLE VIEW OF THE SPACE TOPOLOGY. THE CURVE HIGHLIGHTS THE PERFECTLY NESTED STRUCTURE, WITH GENERALIST AT THE TOP LEFT AND SPECIALIST AT THE BOTTOM-LEFT/TOP-RIGHT.

Survey responses from students that did not finish the entire survey or who indicated that they did not use any tools in the space were omitted from the analysis. This resulted in 54 students for Fall 2020, 178 students for Spring 2021, and 77 students for Spring 2022. Tool usage was then analyzed by category such as demographic, major, and usage type.

A free response question was also included: "If you did not use the university makerspace as much this semester as previous semesters or at all, why?" The answers to this question were coded based on five categories: Remote Learning, COVID Restrictions, Other Restrictions or Policies, No Need, and Other. The "Remote Learning" category was used when students mentioned being enrolled in online classes or not being physically present on campus. The "COVID Restrictions" category was used for any other response that mentioned COVID-19. Some responses were assigned more than one applicable category. Two raters independently categorized a subset of the answers and then discussed the assigned categories. The percentage agreement of this preliminary subset was 63%. Following the discussion and alignment, both raters categorized the remaining responses, and the percentage agreement was recalculated to be 85%. Most of the ratings that did not align were the result of one rater assigning two categories and the other only assigning one category.

2.2 Network Creation

Responses from the survey were used to generate a network that would allow for analysis of nestedness and connectance. The network was modeled as a bipartite network where "students" interact across with "tools" exclusively [4, 21]. An example of the bipartite network graph is shown in Fig. 1b. The network was populated from the student's self-reported tool usage in the end of the semester survey with a "1" indicating they used a tool and a "0" indicating the tool was not used. The values were then used to generate a table like the one found on Fig. 1c and the process was completed for both the general tool categories as well as the specific group categories. With the networks generated, the nestedness and connectance analysis can be conducted.

2.3 Nestedness Analysis

A nestedness analysis requires the generated network to be ordered with "generalists" trending to the top-left and the "specialists" to the bottom-right creating a triangular structure, like the one shown in Fig. 1c [15, 16]. A makerspace with a highly nested network would have a "generalist" tool interacting with a wide variety of students from varying majors, while a "specialist" tool would primarily only interact with students who are already well versed in the space and use a wide array of tools. A "generalist" student would interact with a wide variety of tools of different types while a "specialist" student would interact with a tool that a variety of students use, such as a 3D printer [15]. Thus, a highly nested environment would typically be desired as students are being introduced to more general tools first before diving deeper into the more difficult, specialized tools. By tracking nestedness across semesters and seeing how the value changes in the face of disturbances, it can be seen if students are still utilizing the "generalist" tools or if barriers have become severe enough that they are affecting the use in the space.

A sample highly nested makerspace is found in Fig. 1. The process of calculating nestedness is summarized in Eq. 1 and 2 and was done utilizing a MATLAB software [22] which utilizes the NODF method for calculating nestedness [15, 16]. A value of 1 indicates a perfectly nested network (like the one in Fig. 1) and a value of 0 indicating a non-nested network.

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

In Eq. 1, M_{ij} is the nestedness of the row pair, n_{ij} is the number of ones that match between row i and j, k_j and k_j are the number of one's in row j and i respectively. Nestedness for that row pair is zero if the decreasing fill condition is not met. Otherwise, the second part of Eq. 1 is used. The process is conducted for all row pairs. The same process is followed by the columns. Equation 2 combines all the column and row NODF values and provides the final normalized value, where m is the total number or rows and n is the total number of columns in the network [22].

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

2.4 Connectance

Connectance (Eq. 3) quantifies the actual interactions within a network (L) compared to the total number of potential interactions in a network based on the number of students (N_{rows}) and tools ($N_{columns}$). The bipartite makerspace model used here results in connectance easily quantifying how many tools students are using in a space. Higher connectance values mean the students surveyed used more tools in the space. Tracking this metric across semesters provides an overall view of the variety of tools students used across semesters. When paired with nestedness and survey results it can also be determined what caused drops in tool usage.

$$C = \frac{L}{N_{rows} N_{columns}} \quad (3)$$

2.5 COVID-19 Restrictions

TABLE 2: LIST OF RESTRICTIONS IN THE SPACE ACROSS THE 3 SURVEYED SEMESTERS. COVID-19 RELATED RESTRICTIONS WERE IN PLACE FALL 2020 AND SPRING 2021. SPRING 2022 HAD NO COVID-19 RELATED RESTRICTIONS.

Restriction	FA'20	SP'21	SP'22
Only one person allowed per group	X	X	
Certain tools required request only	X	X	X
Sign up before coming to space required	X	X	
Table space restricted	X		
PPE Requirements	X	X	X
Training before using the space required	X	X	X
General student hangout areas not allowed	X	X	
Masks required in space	X	X	
Club NOT allowed in space	X		

Table 2 lists the restrictions in each of the spaces during COVID-19 impacted semesters, where "X" indicates that a restriction was present. Further restrictions were in place for certain tool groups and are summarized in Table 3. Campus wide restrictions also changed across semesters. Fall 2020 had classes almost fully online, with minimal campus presence. Spring 2021 had classes resumed in person with mask requirements and space occupancy limits. Campus operations were largely back to a pre-pandemic state by Spring 2022.

TABLE 3: GENERAL TOOL CATEGORIES WITH OVERALL RESTRICTIONS.

	Tool Categories	Requires Training	Used for Class	Student Use Minimal Supervision
1	3D Printing	X	X	X
2	Metal Tools	X	X	X
3	Laser Cutter	X		
4	Wood Tools	X		X
5	Handheld Tools		X	X
6	Electronic Tools		X	X
7	Studied at the Space			X
8	Got Help		X	
9	Crafting*	X		
10	CAD Station*	X	X	
11	Paint Booth**			X

3. RESULTS

3.1 Survey Results

Table 4 shows the demographic and major breakdown of the survey participants each semester. While most percentages remain similar across semesters, there were large changes in major. Fall 2020 has the largest percentage of electrical engineers while Spring 2022 has the largest percentage of mechanical engineers. The percentage of students who used the space for studying also changed substantially. A drastic increase is seen between Spring 2021 and Spring 2022 when many COVID related restrictions were removed. The Fall 2020 data is unexpectedly high, especially given that students were not allowed to study in the space at all this semester. One hypothesis is that students considered nearby study space as being part of the makerspace and thus filled out the survey inaccurately.

Figure 2 depicts the percentage of students who used each general tool group for the three semesters. The general trend for most tool groups is a drop in usage percentage from Fall 2020 to Spring 2021, and a rise in usage percentage from Spring 2021 to Spring 2022. These results were unexpected given there were no large changes in COVID policies for the Spring 2021 semester, however they may be a result of the classes that were offered each semester. The metal tools and got/gave help categories show a consistent upward trend across the three semesters unlike the rest of the tool groups.

Figure 3 shows the difference in tool usage for students who used the space for class vs those who did not. The percentage usage is higher for those who used the space for class for most tool groups. The trends between semester are also consistent. The students who use the space for class and used metal tools follow the same upward usage trends seen in Fig. 2. Students who did not use the space for class and used metal tools have a steep drop off in usage in Spring 2021. This could indicate that class requirements are a primary reason metal tool usage increased despite COVID-19. A similar spike in usage was seen for got/gave help.

TABLE 4: STUDENT DEMOGRAPHIC BREAKDOWN ACROSS SEMESTERS. *N/C DENOTES DATA WAS NOT COLLECTED THAT SEMESTER. **VALIDITY OF DATA IN QUESTION GIVEN THE MAKERSPACE RULES.

	Demographic	FA’20 N = 54	SP’21 N = 178	SP’22 N = 77
Gender	Man	80%	66%	65%
	Woman	13%	32%	27%
	Prefer Not to Disclose	7%	2%	8%
Ethnicity	Hispanic	15%	22%	23%
	Non-Hispanic	81%	74%	70%
	Prefer Not to Disclose	2%	4%	4%
Race	White / Caucasian	69%	67%	61%
	Black or African American	2%	2%	0%
	American Indian or Alaskan Native	4%	2%	3%
	Native Hawaiian or Other Pacific Islander	0%	0%	0%
	Middle Eastern	0%	2%	1%
	Asian	26%	21%	29%
	Prefer Not to Disclose	2%	6%	8%
Major	Aerospace Engineering Major	9%	4%	4%
	Biomedical Engineering Major	0%	5%	5%
	Chemical Engineering Major	0%	1%	0%
	Computer Engineering Major	4%	2%	1%
	Electrical Engineering Major	30%	10%	12%
	Industrial Engineering Major	0%	13%	0%
	Material Science and Engineering Major	0%	1%	0%
	Mechanical Engineering Major	54%	51%	73%
	Nuclear Engineering Major	0%	0%	0%
	Other Major	4%	13%	5%
	Non-Mechanical Engineering Major	46%	49%	27%
Class	Used Makerspace for a Class This Semester	70%	84%	60%
	Did Not Use Makerspace for a Class This Semester	30%	16%	40%
	Used Makerspace for Capstone This Semester	30%	26%	44%
	Used Makerspace for Non-Capstone Class This Semester	44%	60%	22%
First Gen	First-Generation College Student	*N/C	9%	6%
	Not a First-Generation College Student	*N/C	90%	92%
Studied	Studied in the Makerspace This Semester	**22%	5%	22%
	Did Not Study in the Makerspace This Semester	78%	95%	78%
Credits	Freshmen	0%	1%	4%
	Sophomores	20%	11%	8%
	Juniors	17%	24%	9%
	Seniors	61%	65%	77%

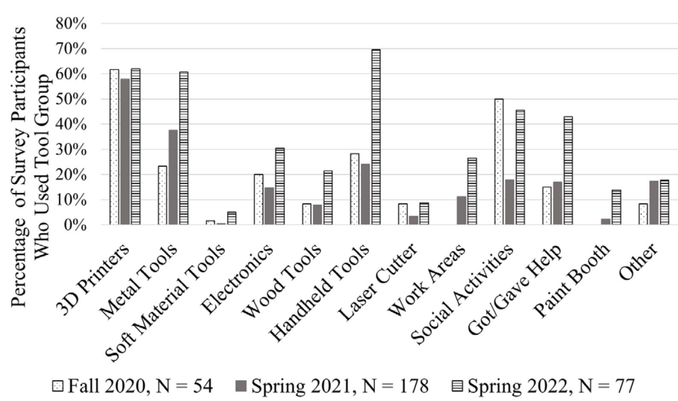

FIGURE 2: PERCENTAGE OF STUDENTS WHO USED A TOOL IN THE 11 GENERAL TOOL GROUPS (TABLE 3) IN FALL 2020, SPRING 2021, AND SPRING 2022.

Figure 4 shows tool usage differences for students who studied in the space vs those who did not. The trends remain relatively constant throughout semesters with students who study in the space showing slightly higher tool usage. The largest difference is shown in the got/gave help category where those who studied have a much higher percentage. Studying is categorized as a social activity which is why there is 100% usage in this category for those who studied in the space.

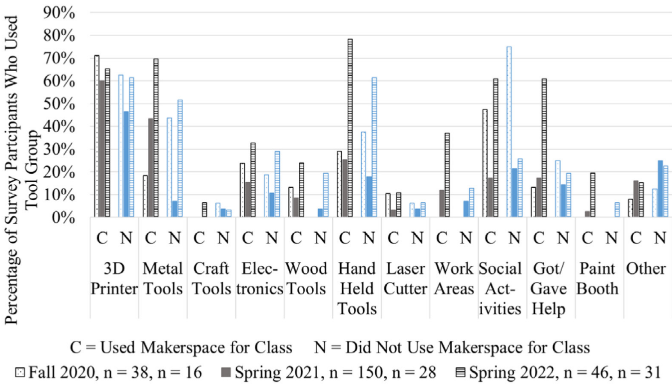

FIGURE 3: TOOL USAGE COMPARISONS ACROSS 3 SEMESTERS BETWEEN STUDENTS WHO INDICATED USING A TOOL DUE TO A CLASS REQUIREMENT (C) AND THOSE WHO DID NOT (NC).

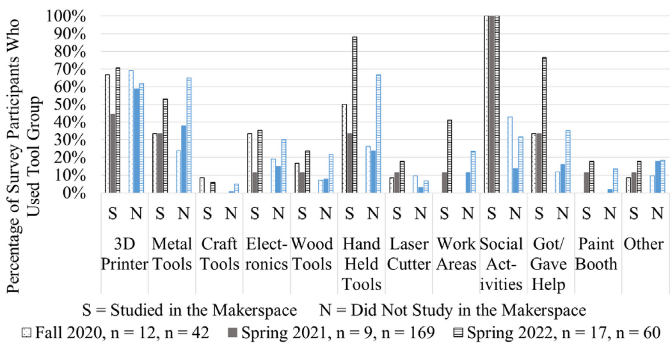

FIGURE 4: TOOL USAGE COMPARISONS ACROSS 3 SEMESTERS BETWEEN STUDENTS WHO INDICATED STUDYING IN THE SPACE (S) VS. THOSE WHO DID NOT (N).

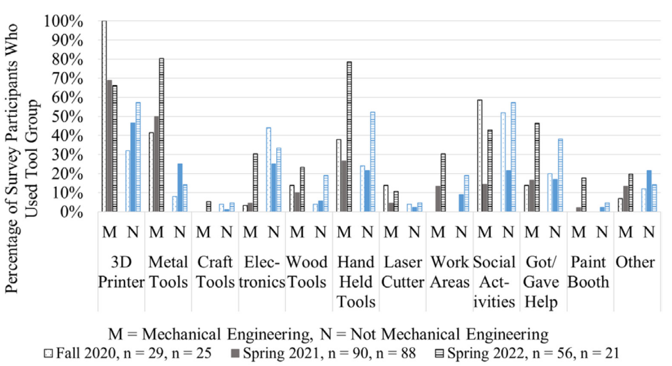

FIGURE 5: TOOL USAGE COMPARISONS ACROSS 3 SEMESTERS BETWEEN MECHANICAL ENGINEERING STUDENTS (M) AND NON-MECHANICAL ENGINEERING STUDENTS (N).

Finally, Figure 5 shows the difference in trends between mechanical engineering students and non-mechanical engineering students. The general upward trend of metal usage is seen for the mechanical engineering majors, and not reflected in the other majors. This is very similar to the pattern seen for class usage of the space. Other trends such as men versus women usage and Hispanic vs non-Hispanic student usage were examined, but no major differences in their relation were seen over the three semesters.

TABLE 5: REASONS STUDENTS USED THE MAKERSPACE LESS THAN PREVIOUS SEMESTERS.

Reason	FA2020 (46% Answered)	SP2021 (40% Answered)	SP2022 (10% Answered)
Remote Learning	18%	12%	9%
COVID Related Restrictions	39%	42%	0%
Other Restrictions/ Policies	14%	8%	9%
No Need	21%	37%	55%
Other	7%	1%	27%

Table 5 shows the responses to the question “If you did not use the university makerspace as much this semester as previous semesters or at all, why?” The percentage values represent the ratio of students who mentioned that reason to the number of students that answered the question. The percentage of students who did not use the space due to remote learning and online classes decreased each semester. On the other hand, the percentage of students who specifically mentioned COVID related restrictions increased between Fall and Spring, potentially due to the fact that more classes resumed in person learning and more students had reason to try and use the space. By Spring 2022, most of the students who used the space less did so only because they had less need for the equipment. Between 8% and 14% of students each semester also mentioned other restrictions or policies that made it annoying and inconvenient to use the space.

3.2 Network Results

Nestedness and connectance were calculated for each semester, with results summarized in Fig. 6. Connectance and nestedness were the highest during the Spring 2022 semester, when the COVID-19 restrictions where lifted for the space. The lowest values were found during the higher restriction semester, with Spring 2021 having the lowest nestedness and connectance values. Results from the values are consistent with results found in the overall survey data, with the students surveyed for each semester having an overall higher interaction rate with tools during the Spring 2022 semester as compared to previous semesters, and with Spring 2021 having the lowest percentage tool usage for the surveyed population as seen with the connectance. The network analyzis here helps quantify exactly how *much* student usage increased during the no restriction Spring 2022 semester, with the conntance increasing almost double from previous semester. The increased nestedness value along with the connectance indicates students were utilizing a wider array of tools, more than just the general tools but also specialized tools. While the values can provide this insight, the survey information is needed to see which tools students are utilizing at higher rates.

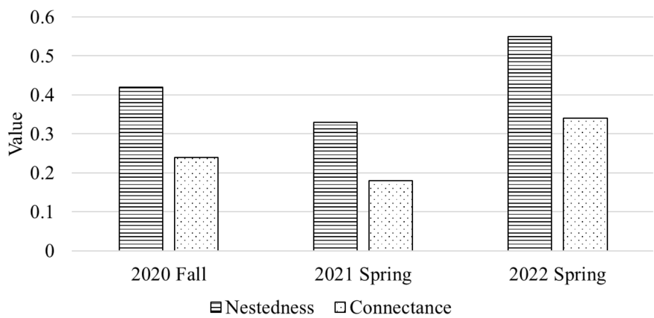

FIGURE 6: NESTEDNESS AND CONNECTANCE VALUES ACROSS ALL THREE SEMESTERS.

4. DISCUSSION

The effects of the COVID-19 restrictions played a major role in the usage of the space. Figure 2 indicates higher tool usage across most of the general tools as more restrictions were lifted and Table 5 highlights COVID-19 restrictions as a major factor limiting usage of the space. These responses dropped to zero in the subsequent Spring 2022 semester with no student indicating restrictions to COVID-19 as a reason for not using the space. Figures 3 and 4 follow similar trends to the general tool usage, with overall usage increasing between semesters with COVID restrictions and those without. Additionally, students that studied in the space utilized a larger number of tools that those who did not, despite accessibility being highly limited during the COVID semesters. Overall, in most of the survey results, Spring 2021 had the lowest usage in tools across most categories. Although COVID restrictions were also in place in Fall 2020, many students did not use the space at all this semester. Those who did had significant reason to and therefore there was not as low of a percentage usage. In Spring 2021, once students acclimated to the restrictions, percentage tool usage was at its lowest. One tool category that strayed from the pattern is metal tool usage. Students studying mechanical engineering make up a large percentage of the metal tool usage, as can be seen in Fig. 5. The steady increase through semesters despite the overall lower trend of Spring 2021 may be attributed to classes that continued to introduce mechanical engineers to the space as they adapted their curriculum to the heightened restrictions. This is supported by the increased metal usage of students who used the space for class requirements seen in Fig. 3.

Network analysis results provided insight into the current "health" of a makerspace with a *measurable* value indicating its performance that otherwise could not be found. On the other hand, survey information provides a more in depth, nuanced view as to the *why* a space may be experiencing challenges. The network metrics summarized in Fig. 6 were able to identify that conditions were not as they were normally expected, with the connection being the highest during the Spring 2022 semester as well as the nestedness indicating a healthy, robust space. However, while the metrics can be used to provide an overall view of how the space is performing that can be easily measured across time, a more in-depth survey analysis to see which specific tools are being used more than others as well as evaluating the overall trends is still needed to fully evaluate how the makerspace is performing. The higher initial nestedness despite the first semester of COVID-19 restrictions being in place could indicate the space had some initial resistance to change. The following semester drop in nestedness despite restrictions slowly being lifted can be an indicator of the lower-than-normal operation nestedness, indicating the health of the makerspace decaying.

5. CONCLUSION

The COVID-19 restrictions had a large impact on the tool usage in the makerspace with tool usage being down due the increased restrictions and bouncing back when the restrictions were lifted. This highly restrictive scenario can be used to, in the future, see if there are restrictions potentially affecting the space. Using traditional survey gathering techniques and ecological network analysis, a better understanding on the difference between the semesters could be gathered. Survey data highlighted the decrease in usage of specific tools, as well as the barriers students faced that may have caused these decreases in usage. Identification of which tools improved, such as metal tools, as restrictions were slowly lifted could be identified. On the other hand, the network metrics provide insight into the overall health of the makerspace, with the higher restriction COVID semesters seeing a decrease in both connectance and nestedness when compared to the lower restriction Spring 2022 semester. With results gathered from this survey, utilization of survey metrics as well as network analysis to evaluate makerspace health across semester would be used to identify challenges easier. The network metrics would allow for the monitoring of the space by providing measurable values to see how the space changes across time.

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