Makerspaces for the Multitudes - Strategies to Expand Access and Use of a College Makerspace

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Introduction

This evidence-based practice paper reports the effectiveness of various strategies to support growth in the use of campus makerspaces both in numbers of students and the diversity of background and major. Makerspaces have increasingly become part of the landscape of colleges and universities over the past decade, especially in engineering colleges where experiential learning and design experiences are viewed as essential building blocks in educating new engineers [1]-[3]. Although it is exciting to have these new spaces filled with prototyping tools, professional support, and sets of student super-users, it is imperative that college makerspaces be accessible, available, and intriguing to the breadth of students enrolled if we want these particular resources to positively impact more than a fraction of the student body. Institutions may find it simplest to serve a subset of students already inclined toward innovation and entrepreneurship, but maintaining a sense of balance and driving a diverse set of users into these spaces is a critical goal [3]. Considering the resource-intensive nature of such spaces, their continued value depends on engagement with a critical mass of students participating in meaningful and value-adding experiential learning activities.

Toward that end, analysis of usage continues over three years at a makerspace situated in a large public research university in the upper midwest. Students access the makerspace via courses held in the space, through open visits, and by registering for and attending short courses--dubbed

Microcourses--taught there. Over three years, the makerspace has developed three main strategies for driving a diverse and larger set of students from its engineering, math, and physical science majors into the space to serve as a platform for design practice, cross-disciplinary exploration, and community building. The first strategy aims to introduce the makerspace to students as early as possible, hopefully developing an early familiarity and connection to the space. The second is the development of collaborative and structured learning opportunities that encourages the teaching of broad skills and sharing of information within the makerspace, whether in the form of for-credit courses or short and accessible Microcourses. The third is to leverage web and social media to create excitement around student design projects and experiential learning in the makerspace while growing the overall sense of community.

Considering these strategies, this research study addresses the following questions.

1. How has the demographics, in terms of student major, gender identity, and racial identity changed over the first three years of use?
2. To what extent have these three strategies, and the initiatives they spawned, impacted that change?
    a. Early exposure
    b. Structured learning opportunities
    c. Marketing and communication

Background

First opened in the spring of 2017, the Anderson Student Innovation Labs at the University of Minnesota are a set of makerspaces designed to give the people in the College of Science and Engineering (CSE) safe access to physical prototyping resources and experiential learning opportunities. Combined, the three locations contain 3D printers, laser cutters, CNC mills and lathes, traditional metal and wood working tools, 3D scanning and measurement machines, electronics prototyping and testing equipment, a variety of hand tools, collaboration spaces, design software, and storage space for CSE students, staff, and faculty to use. The labs offer training and guided workshops to hone students' skills and since the labs serve as a nexus of maker activity within CSE, lab users also benefit from interacting with each other. By consolidating its making resources into the Anderson Labs, CSE has been able to expand its design and manufacturing related coursework, relieve faculty from some maintenance and repair overhead associated with prototyping equipment, and support more student initiated/student led projects.

Use of the makerspace is free to all University of Minnesota students although about 90% of student visitors are CSE students who also receive, at no-charge, an allotment of 3D printing material each semester to encourage use. 24/7 access is available for large portions of the space

after completing a short orientation course and signing off on a user agreement. The space has one full-time staff member who oversees 12-20 student workers. Partial FTEs are also allotted from elsewhere in the college to assist with communications, purchasing, accounting, and other administration.

At the initial launch of the makerspace, a committee of faculty and staff with a connection and interest in experiential design experiences across the College of Science and Engineering was formed to guide the direction of the new space. One of the first orders of business was to set some guiding principles by collecting possible priorities for the space and then surveying the committee to set hierarchy based on importance and ease of implementation. Some low-hanging fruit was identified and implemented such as digital signage and access to video equipment. Beyond that the committee identified the following priorities for the space:

1. Encourage a diverse set of student users within the College of Science and Engineering.
2. Create a better web and social media presence.
3. Develop technological currency in the student body.

The first priority was identified as the most important with the other two priorities to be carried out with an eye toward the first. A couple challenges affect the primary goal. First, unlike most U.S. research institutions with a seperate college of engineering, CSE grants degrees in the physical sciences, math, computer science, and engineering. Students in science and math are less encouraged by their course curriculum to seek out the use of design and prototyping resources so those students need additional programming and attention if the Anderson Labs is to more closely reflect the diversity of the college as a whole. Second, the primary space is located in the Mechanical Engineering building compounding the reality that students majoring in mechanical engineering are the most inclined to seek out design and prototyping space due to their own interests or due to course requirements. Neither of these realities are fundamentally negative, but instead outline and inform the necessity to develop opportunities and programs that appeal to the full complement of students within the college. These three early priorities formed the basis for the four ongoing initiatives described below and currently active in the Anderson Labs.

For the first initiative, the Anderson Labs and the College of Science and Engineering has worked to grow a collection of prototyping courses aimed at first year students. Integrating classroom activities into a makerspace may be beneficial if done with care to ensure the course instruction and assignments do not completely monopolize the facility. Some successful strategies for careful integration include using separate classroom facilities for the majority of class instruction, setting aside specific times for the class to use the makerspace, and spacing project due dates throughout the semester. With a structure like this in place, course integration into a makerspace improves utilization of the facility, provides a motivator for students to

become familiar with the space, and may increase student utilization of the space later in their educational tenure. At the Anderson Labs we have implemented two very successful courses: CSE 1012 and ME 2011. CSE 1012 is a first-year, second-semester course that introduces students to project-based learning utilizing one of three topic areas. The current topic areas include 3D Printing, Micro-Controllers, and Sensor Data Collection and Processing. In all cases, students spend half the semester doing tutor-guided and self-guided hands-on learning activities to develop a critical mass of skills. The second half the semester students work on an open-ended group design project defined by the students themselves. ME 2011 is a second year design course for mechanical engineering majors that requires the design and construction of a robot.

The second initiative takes this idea of early exposure to its earliest possible derivation by having all incoming CSE freshmen come through the Anderson Labs during summer orientation. The hope is this early exposure helps break down any barriers for later visits and helps diversify the set of students exposed to and comfortable in the makerspaces. This initiative continues to develop as the first year contained only a brief overview and walk-through of the makerspace while the following summer scheduled more time and allowed for an interactive, team-oriented, activity where the 15-25 students in each session had to free the university mascot from an enclosed “escape room” by finding clues and using equipment such as laser cutters and 3D printers in the makerspace.

The third initiative is the development of Microcourses, basically very short trainings, workshops, or events that students sign up for and complete. The Microcourses have their own transcript and prerequisite tracks mimicking their academic pursuits and are officially recorded in transcript form to share with employers or other interested parties. Courses include a basic orientation, trainings on 3D printing, laser-cutting, soldering, welding, and more basic skills, plus special events hosted by student groups, industry, or other sponsors. Microcourses are usually taught by staff, including student staff, but also by fellow students who wish to train members in their student groups, recruit additional students to their groups, or simply share their passion for design and making. All courses are coordinated and approved through the Lab Manager and generally have a Canvas section (our university’s adopted Learning Management System) associated with it to provide pre and post work, documentation, and easy communication.

The fourth initiative involves communication, including an improved website, digital signage, and a social media presence. To further this initiative, a student position was dedicated to communications and part of an FTE from the college level communications team assisted with upkeep of the website. Digital signage is kept current, relevant, and consistent across the various spaces and there are 2-3 social media posts a week highlighting events, student projects, and makerspace news such as the unboxing of a new high-end 3D printer.

Methodology

Multiple data sources exist to analyze the use of the makerspace. The most thorough is the mandatory check-in kiosk at each of the entrances. Students can use their campus IDs to check in or type in their student ID number. Lab/makerspace orientation data have also been collated giving a picture of the students who sign up for a short orientation and receive 24/7 access to the space. Both of these data sets are cross referenced with demographic information giving a full picture of utilization. This cross-referenced data is from semesterly census data, thereby identifying students as they were when they visited or when they went through orientation. Although users are asked to check in each time they enter the lab, enforcement is sporadic at best. To address that issue, the data is presented as unique visitors during each semester, treating a student who checks in once the same as one who checks in multiple times (but creating another limitation in the dataset related to high-frequency users). Orientation data offers a different perspective focusing especially on understanding trends related to new users. Although users aren't required to take an orientation, most do when they initially discover the space to obtain after hours access.

Class roster data exists for the various courses that are taught in the Anderson Labs offering another measure of growth. Additionally, students in CSE are allotted up to 500 grams of PLA 3D printing material each semester and the number of students using the PLA and how much is tracked. Wrapping up visitor data, we have Microcourse sign-up data as students sign up for short courses that teach various skills related to the equipment in the lab and design in general.

Finally, we have survey data from two separate surveys with some intentional question overlap. The first was administered in April/May of 2018 and the second in December of 2019, allowing us to discern any shifts in responses as our initiatives began to mature. Another useful, if limited metric relates to web visits and social media activity putting some data behind our enhanced communication and marketing efforts.

All of this data has been analyzed and the most relevant data points related to the research questions above are detailed below.

Results

Overall Growth Analysis

Looking at visitor and orientation trends since the semester after the opening of the Anderson Labs, it is clear that there has been tremendous growth. The first set of data looks at unique visitors by semester from Fall 2017 through Fall 2019 excluding summers which did not have

reliable visitor tracking. The data in Table 1 is only undergraduate student visits, excluding visits by graduate students, staff, faculty, and outside visitors. For context, the space is primarily an undergraduate space. Of the 4296 recorded unique student visitors over this time frame, 91% were undergraduate students at the time of their visit.

Table 1: Unique CSE visitors and share of total by major category, gender identity, and ethnic identity.

Major Category (Share of all CSE UGs over period)	**Fall 2017**	**Spring 2018**	**Fall 2018**	**Spring 2019**	**Fall 2019**
Science and Math (33.4%)	39 (8.8%)	58 (9.6%)	88 (10.7%)	126 (11.6%)	108 (11.5%)
Mech Engr (14.4%)	199 (45.0%)	215 (35.6%)	376 (45.7%)	377 (34.7%)	396 (42.2%)
Other Engr (51.2%)	201 (45.5%)	330 (54.6%)	352 (42.8%)	582 (53.5%)	426 (45.4%)
Undecided (1.1%)	3 (0.7%)	1 (0.2%)	7 (0.9%)	3 (0.3%)	8 (0.9%)
Gender Identity					
Female (28.1%)	99 (22.4%)	166 (27.5%)	191 (23.2%)	288 (26.5%)	238 (25.4%)
Male (71.8%)	343 (77.6%)	436 (72.2%)	631 (76.7%)	799 (73.4%)	700 (74.6%)
Undefined (0.1%)	0	2 (0.3%)	1 (0.1%)	1 (0.1%)	0
Ethnic Identity					
Non-white or Hispanic (28.8%)	91 (20.6%)	127 (21.0%)	194 (23.6%)	289 (26.6%)	247 (26.3%)
White (68.8%)	344 (77.8%)	469 (77.7%)	604 (73.4%)	779 (71.6%)	665 (70.9%)
Not selected (2.4%)	7 (1.6%)	8 (1.3%)	25 (3.0%)	20 (1.8%)	26 (2.8%)
Total	**442**	**604**	**823**	**1088**	**938**

Table 1 looks at visitors broken down by major categories, gender identity, and ethnic identity and excludes visitors from other colleges (9.0% of undergraduate visitors over this time period). The number of unique visitors has increased considerably and use each spring is higher than use each fall by a small but significant amount. Although not studied, this discrepancy between fall and spring is likely due to a number of factors including senior design courses having higher enrollments for spring semesters and student group design and build activity being higher in the spring. Growth is a goal in itself and this data demonstrates that over twice as many students made a visit to the Anderson Labs this past semester than the semester after it initially opened.

Figure 1 isolates declared and intended major data for students. Growth has increased substantially across all major groups. In terms of major category, Mechanical Engineering (ME) major share is higher each Fall due to a required Sophomore level design course (ME 2011) in the major that is partially held in the Anderson Labs space and drives visits by those students due to course requirements that started in Fall 2018. Despite a key part of the curriculum driving students in ME to the space, their share of visitors has dropped from 41.4% of visitors in the 2018 calendar year to 38.2% for the 2019 calendar year, offset by similar increases from both the science and math majors and the other engineering majors.

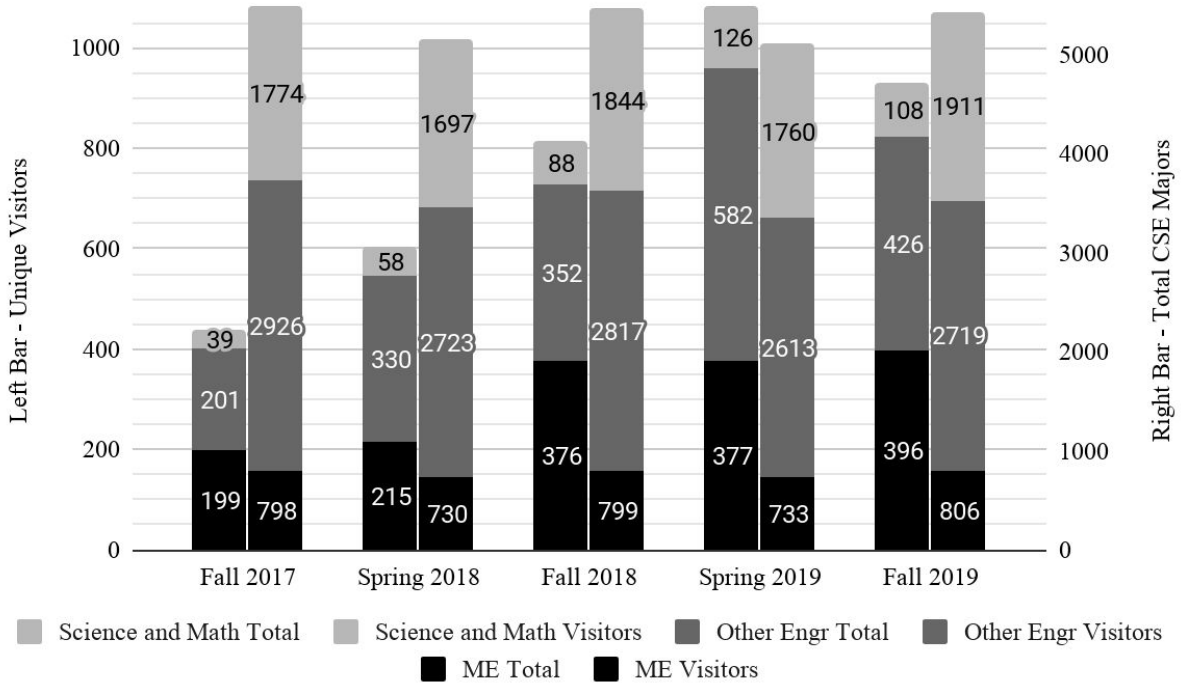

Figure 1: Unique Visitors by CSE Major Compared to Total CSE Student Population

Figure 2 visualizes the changes in terms of gender and ethnic identity. We also see small, but positive trends, not quite reaching parity, but inching closer. For the most recent semester,

female visitors to the Anderson labs made up 25.4% of visitors while making up 28.5% of all CSE students. In terms of ethnic identity, there is a clearer trend toward parity with non-white and Hispanic students growing from 20.6% in Fall 2017 to 26.3% in Fall 2019. For Fall 2019, non-white and Hispanic students made up 30.1% of CSE students. As the Anderson Labs has become more of a fixture within the college, it has trended toward being representative of the student body studying in the college, albeit at a slow and steady pace.

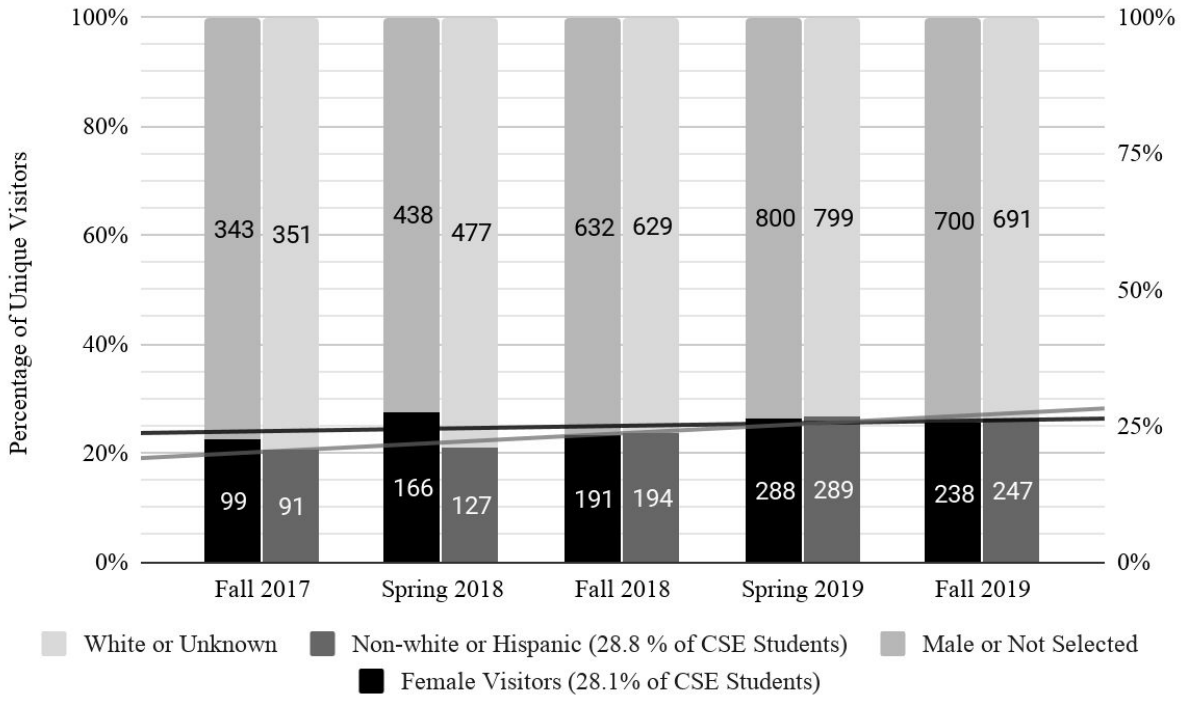

Figure 2: Gender and Ethnicity as a Percentage of Total Unique Visitors

Figure 3 represents another method to measure activity in the Anderson Labs. Although this data is not linked to demographic data, it further demonstrates the increased activity in the space and demonstrates that not only are more students visiting the space but they are getting more "work" done. Students in the college are alloted 500 grams of PLA filament each semester which is tracked and checked out in the main Anderson Labs space. Figure 3 represents the number of average check-outs (>1g) per month by semester. The trend is quite clear and the data further illustrates that the spring semester is generally busier than the fall semester.

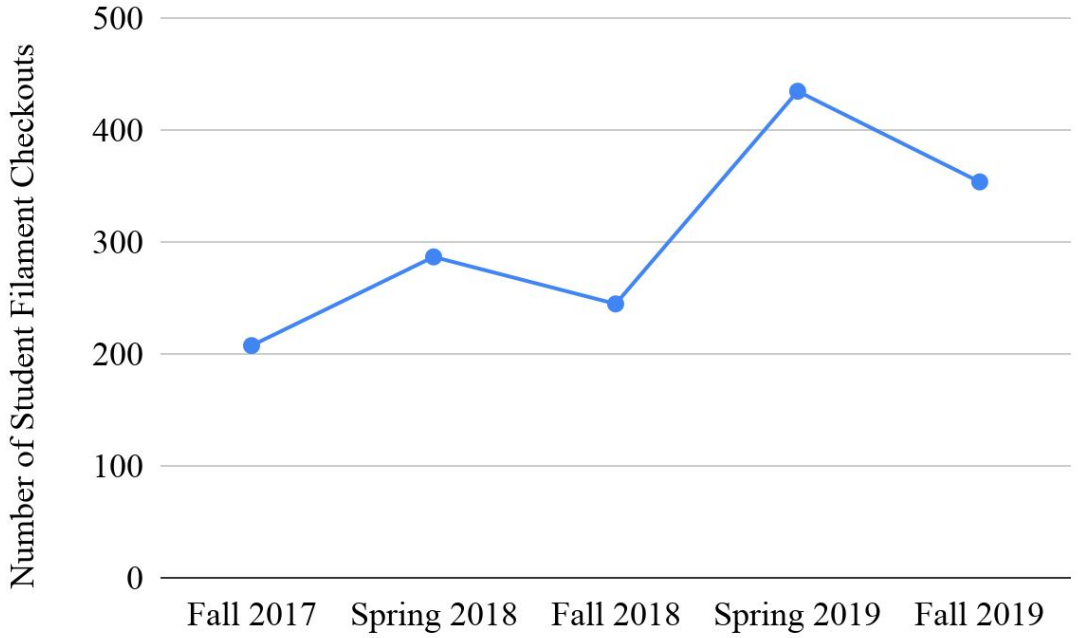

Figure 3: Average filament check-outs per month by semester

Early Exposure

The second research question attempts to understand the impact of various initiatives on overall growth and goals to diversify the use of the space. One strategy employed in the space was to expose students to the space during their first year and took two forms. One initiative involved the development of a college-wide design and prototyping course (CSE 1012) open only to first-year students and offered in their second semester. This course is held in the Anderson Labs and has developed from a four section course of 24 students in Spring 2017 that only had 3D printing as a topic to an eight section course for Spring 2020 with options for 3D printing, 3D printing and microcontrollers, and microcontrollers and sensors.

Table 2: Design and Prototyping (CSE 1012) Course Return Rate for Following Semester

	Fall 2018 Visit/Spring 2018 Total Cohort	**Fall 2019 Visit/Spring 2019 Total Cohort**
CSE 1012 Return Rate	52/70 (74.3%)	73/133 (54.9%)
All First Year Student Visit Rate	240/1150 (20.9%)	217/1114 (19.5%)

Table 2 compares student return rate to the Anderson Labs the subsequent semester for a visit. It is very clear that students who take CSE 1012 are much more likely to return on their own to the Anderson Labs, even if it is not possible to discern how much of this is due to these students already being inclined to use the Anderson Labs resources and how much is attributable to having taken the course. It is curious that as the course scaled up from Spring 2018 to Spring 2019, the return rate decreased. Regardless, it seems likely that this type of design and prototyping course that introduces students to utilizing the Anderson Labs in a structured and faculty-led manner is an excellent method for ingraining a "maker" mentality in students at an early stage that leads to further utilization.

Table 3 looks at how many first year students visited the lab and took part in a makerspace orientation session in their first year. This analysis is an attempt to track the effect that exposure to the Anderson Labs during freshman summer orientation or otherwise in their first year has on engagement in the Anderson Labs.

Table 3: Unique Visitors and Makerspace Orientations for First Year Students

	Fall 2017	**Spring 2018**	**Fall 2018**	**Spring 2019**	**Fall 2019**
Unique Visits	106	160	130	269	155
Completed ALabs Orientation*	Not Available	41	86	176	213

*Fall 2017 makerspace orientation data not available and Fall visitor data includes the previous summer period as well.

To understand this data, the evolution of first exposure and lab orientation must be explained. For students entering the Fall of 2017, there was no formal exposure to the Anderson Labs during freshman orientation. For Fall 2018 students, there was a brief 15 minute tour of the Anderson Labs during freshman orientation. For Fall 2019, all students participated in a 45 minute interactive session that served as part of the Anderson Labs Orientation. They could have completed the orientation online if they so chose. The strategy here was to expose the students to a meaningful connection to the space with the possibility for followup, hoping it would spur further engagement in the Fall. In terms of total visits in the Fall, the developing strategy of exposure seems to have had some effect as total unique visitors for first year freshmen has grown. It is interesting to note that orientations outnumbered visitors for the recent Fall semester meaning many students completed lab orientation in the summer, but never returned to the space in the Fall.

Structured Learning Opportunities

Returning to courses that utilize the Anderson Labs, CSE 1012, the college-wide design and prototyping course for first-year students, had a positive effect, as shown in Table 2, on return rate. One other course, ME 2011--a core introductory course for all mechanical engineering majors--has multiple sessions taught in the Anderson Labs. Similar to CSE 1012, ME 2011 appears to create the type of familiarity and initiative that brings students back to the space for other reasons. Of course, the major and field is a large caveat here, as mechanical engineering students are more likely to take courses or have interests that directly overlap with the traditional sets of tools found in makerspaces [3],[4]. However, the data is still instructive. Only complete data is available for students who took the course in Fall 2018.

Table 4: Student Visits Before and After Enrolling in Introductory Core ME Course (Fall 2018)

Course Enrollment	**Unique ME 2011 Visitors Semester Before Course/Total Unique Visitors**	**Unique ME 2011 Visitors Semester After Course/Total Unique Visitors**
212	19/604 (3.1%)	73/1088 (6.7%)

Although it appears that enrollment in a semester long course that utilizes the Anderson Labs is a strong strategy to both diversify use of the space and drive continued activity, it is not realistic that every student will have the opportunity to take such a course. The third initiative to use structured learning opportunities to entice students into the space and increase their technological literacy centered around the creation of Microcourses. Microcourses mimic regular course naming conventions and are offered through the campus's online training infrastructure. Most also utilize Canvas learning management software as do most regular courses on campus. The first Microcourse developed was AL1001, Orientation to the Anderson Labs for Spring 2018. For purposes of the following analysis, AL1001 will not be included as students need to take it to gain 24/7 access. Instead, results will be narrowed to Microcourses that were developed, starting in Fall 2018, to teach specific skills or disseminate information. Unfortunately, completion information is not reliable until the Anderson Labs works out an administratively efficient method of recording completion. Thus, data includes both registration (which may or may not have completed) and completions. Here is a list of the Microcourses that were taught, their frequency, and by whom:

Table 5: Microcourses taught since Fall 2018

Course	**Frequency**	**Instructor Group**
Lean to 3D Print!	Weekly for 3 semesters	Staff

Learn to Laser Cut!	Weekly for 3 semesters	Staff
Wood Lathe for Beginners	Sporadically for 3 semesters	Lab Manager
Introduction to 3D Modeling	Once in Spring 2019	Lab Manager
Minnovate Industry Readiness Program	Semester long program in Spring 2019	Entrepreneurial Student Group
Learn: Battery Building Basics	Once in Spring 2019	Design and Build Student Group
Learn: Mechanical System Design	Once in Spring 2019	Design and Build Student Group
Learn: Electric Motor Design	Once in Fall 2019	Design and Build Student Group
Arduino Pumpkins	Once in Fall 2019	Design and Build Student Group
Electronics Engineering and Manufacturing Crash Course	Once in Fall 2019	Industry Trade Group
Learn to Solder	Once in Fall 2019	Professional Society Student Group

Microcourses have been set up to be flexible in nature, taught by faculty, staff, students representing various groups, and even outside groups. The strategy is to build a broad set of offerings that can appeal to all types of interests and goals. It is an early project and there is not a lot of data to analyze, but as the course offerings have grown there has been an increase in visitors who have taken a Microcourse suggesting that this type of short but structured learning opportunity can be an important component of programming in a makerspace.

Table 6: Unique Visitors Who Have Registered or Completed a Microcourse

	Fall 2018	**Spring 2019**	**Fall 2019**
Microcourse/Total Visitors	35/1012 (3.5%)	118/1354 (8.7%)	157/1130 (13.9%)

Marketing and Communication

In Spring 2018, the Anderson Labs hired an undergraduate student to curate its Facebook and Instagram accounts, develop material for digital signage, and assist in preparing and then

updating a new website. It is not possible to link social media postings and other communication directly to growth, but it is likely a factor in the increased activity in the makerspace. This increased social media and communication activity has, at the least, led to growth in some key social media metrics. Instagram followers have grown from 56 on March 1 2019, just before regular posting started in earnest, to 298 as of January 30, 2020. Facebook followers have likewise grown from 38 to 150 over the same time period. Our new website, launched on the first day of the Fall 2019 semester had 14,552 views during that first semester, compared to 9,566 for the Fall 2018 semester. A concerted effort to increase social media postings and newsletter communications has indeed led to a larger online audience and all campus makerspaces should likely take this type of marketing and communication seriously.

Before digging into what these results mean, here is a bit more context and one last metric. Anderson Labs conducted a user survey in December of 2019 to help understand how the makerspace is functioning and where to make improvements. Of the 288 responses to the question, "how much value do the Anderson Labs add to your University of Minnesota experience," the mean score on a scale from 1 (little value) to 5 (a lot of value) was 4.44. Much like prior research results suggesting the positive impact on multiple facets of students' education, students see value in the Anderson Labs [5]. It is the job of higher education faculty and professional staff to make sure these resources are shared widely and wisely with the full population they serve.

Discussion

Interest in the Anderson Labs has certainly grown over its first few years of existence and we see signs that the use profile is trending toward the overall demographics in the college. There will likely never be symmetry given discipline specific motivations for using the space. However, trends in terms of gender and ethnic identity have trended toward the baseline. The results point toward the importance of early exposure and meaningful structured learning within the space. Considering research in the area of barriers to women and underrepresented minorities use and interest in makerspaces, it is imperative to counter intimidation with collaboration, provide a welcoming environment, give meaning to each visit, and make access as easy as possible [6]-[8]. Getting underrepresented groups in makerspaces early and providing them with structured learning is one promising strategy to achieve this goal and backed up by our results. The Anderson Labs practice of providing 3D printing material and having other material on hand for use is another way to remove barriers.

Early exposure in all forms is likely a solid strategy for activating students for design and prototyping, but given that a full course is not realistic for all students, it is important to offer meaningful experiences along with the exposure. Although the Anderson Labs has increased

exposure for incoming Freshmen, work needs to continue to entice those students back into the space to learn a skill, start a project, or simply play around a bit. Toward that end, we hope to increase the quality and quantity of our Microcourse offerings, exploring ideas like connecting various courses together to build a larger more complex artifact if you take multiple courses across varying skills. Targeted outreach is also an area for exploration, reaching out to those who express some interest but do not take the next step. Early exposure needs to be boosted with meaningful experiences. It is not necessarily easy to deliver meaningful experiences in short periods of time to hundreds of students, but that just makes experimentation and the sharing of best practices that much more important.

Finally, communication in all its forms is a necessary component. Makerspaces in higher education are not core services for students. They are mostly enhancements to their education and student attention needs to be competed for. However, if students engage in the types of activities that naturally occur in higher education makerspaces, we can expect an enhancement of knowledge and skills gained through experience, buoyed by collaboration, engaged in earnestly, and delivered to the multitudes.

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