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DESIGNING HIGH IMPACT CURRICULAR PRACTICES UTILIZING MAKERSPACES

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Synopsis:

Sonoma State University is leading efforts across the California State University system to advance Maker pedagogy. This talk introduces methods to successfully create dynamic makerspaces, campus wide DIY culture, and curricular connections. The talk is ideal for those looking to attract underrepresented STEM groups and interdisciplinary collaborations. The presentation includes lessons learned and methods for funding, assessment, entrepreneurial integration, and institutionalization.

Designing High Impact Curricular Practices Utilizing Makerspaces

With major funding from the National Science Foundation, faculty at Sonoma State University (SSU) have been exploring teaching techniques and curricular designs to optimize student learning, as well as attract students to STEM fields through the use of a campus makerspace. While makerspaces are becoming prevalent across K-16 campuses nationwide, maker pedagogy and research has been primarily focused on K-12 educational environments. SSU has successfully implemented a signature two thousand square foot makerspace (see figure 1), a course in making, *Science 220: Dream, Make, and Innovate* (DMI), and assessment of the program. Maker pedagogy and curriculum looks very different across K-16 institutions. As opposed to K-12 education, university level maker efforts tend to be supported with significantly greater technical infrastructure, integrated with teaching science and technology, and limited to a smaller number of users. Regardless of education level, all maker programs emphasize interdisciplinary and experiential learning, and support an artistic approach to technology. In these educational environments STEAM truly flourishes. For current students, who identify as digital natives, makerspaces provide a bridge back to hands-on, real world experiences.

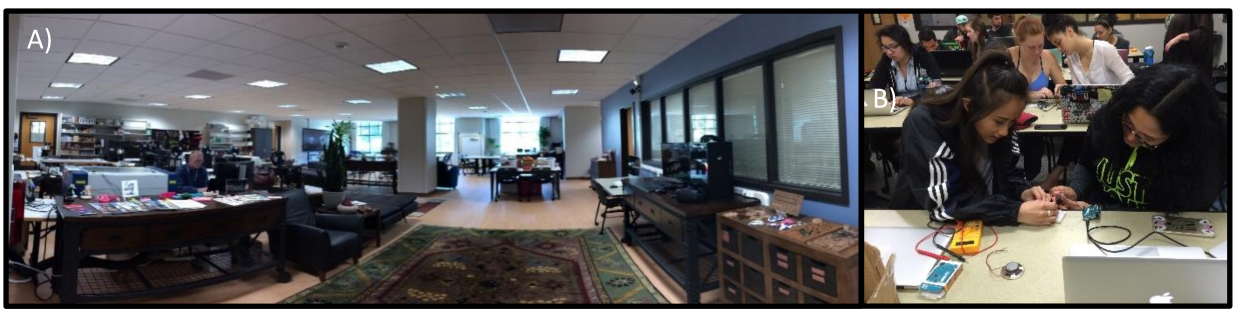

Figure 1. Making at SSU A) SSU Makerspace B) Students engaged in course *DMI*.

Even in these rich constructivist environments, competing elements and dynamics present significant challenges to realizing student learning outcomes. For example, abundant digital libraries of community-sourced 3D models offer a tempting shortcut for students creating original designs. The accomplishments of a design team can mask or hinder individual work. Students often struggle to master both complex digital design programs and traditional fabrication skills. Despite these challenges, early indicators suggest that a makerspace coupled with a making mindset can empower students to work through failure, confidently address and solve problems, imagine creative solutions, improve social interactions, and develop project management and real world, hands-on skills. In our preliminary findings, we have seen significant gains in several student confidence parameters including problem solving and use of technology. In this paper, we introduce the SSU Makerspace and describe our interdisciplinary curriculum, designed to promote STEM education. After two semesters teaching this university level makercourse, we have begun preliminary assessment of student attitudes, learning gains, and retention.

Over the last eight years, SSU as a whole has experienced a gradual increase in retention and graduation rates. In part, this has been due to new university-wide graduation initiatives, in particular courses that focus on transitioning to college life and more intensive faculty advising. Despite these efforts, consistently 40% or less of initially declared STEM majors graduate as a STEM majors. Funding from the National Science Foundation (*STEM Education Through Sophomore Innovation*, $584,000) has been provided to help us investigate ways to 1) attract and retain STEM majors, 2) investigate STEM education using innovative teaching pedagogy, and 3) advance maker pedagogy. We are developing the DMI course to answer two research questions: Are students more likely to (1) enter and/or persist in STEM majors and (2) be successful in learning during STEM related undergraduate courses.

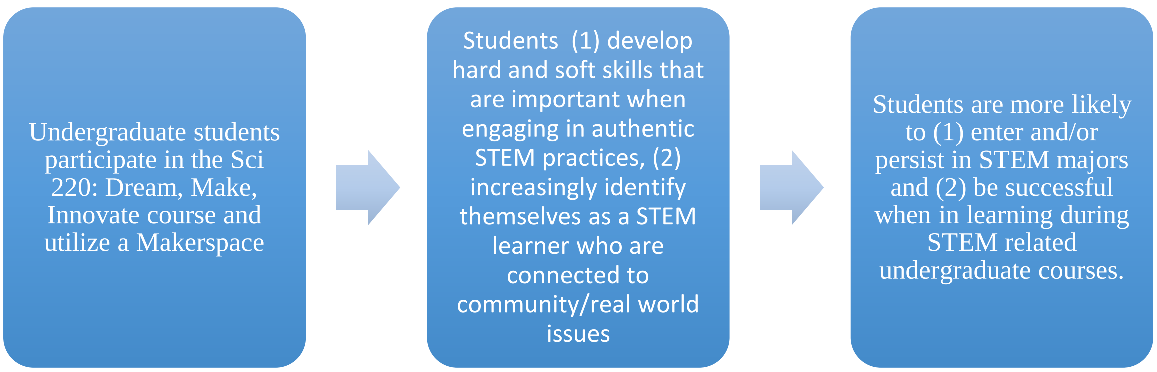

Figure 2. Using *Science 220: DMI* to answer two research questions.

The SSU Makerspace opened in October 2017 and has seen a great deal of media coverage [1]. It is located on the second floor of the SSU Library at the Jean and Charles Schultz Information Center. The creation of the makerspace in the library was the collaboration of the School of Science and Technology, the School of Education, the School of Business, and the University Library. The two thousand square foot open studio focuses on digital fabrication and traditional crafts and is available for any SSU faculty, staff, or students to use. Currently, building materials and filament are supplied without cost to visitors. The space sees about one hundred users a week. The space is operated by student technicians with two present at a time during operating hours. The makerspace is currently open noon to 8pm during week days and supports numerous courses (most before noon open hours).

In 2016, the Dream, Make, Innovate course was first offered as a pilot class with 16 enrolled students and utilized four Lulzbot Mini 3D printers and six Arduino kits. While the pilot showed promise, it suffered from limited resources and an overly ambitious curriculum, which in addition to making and STEM topics, also included a significant focus on entrepreneurship. The current iteration 2017-2018 DMI class takes advantage of the new SSU Makerspace and has 48 students. It also counts towards general education graduation units and has no pre-requisites. Students in the course have very diverse background as shown in Figure 3. 54% of students are majoring in STEM fields; 27% are non-STEM majors including art and humanities; and 19% of the class are undeclared. The student population was also predominantly sophomores. In the future, we would like to reduce the number of juniors and seniors.

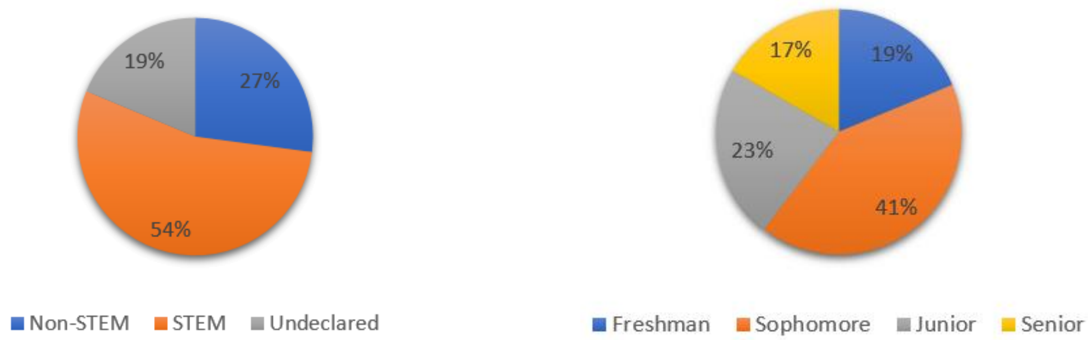

Figure 3. Spring 2018 *Science 220:DMI* Course Demographics.

One of the goals of this course is to introduce students to the hands-on technical and problem solving work that some professionals do in STEM fields, with the hope so that it might interest some non-STEM majors and undeclared students to become STEM majors. During the pilot course and first semester, we noticed that students self-segregated into working groups and cliques of STEM and Non-STEM majors. This at times created an unequal dichotomy. In the second semester, we attempted various mechanism to alleviate this issue. The most successful of these attempts was parsing the class into core groups with specific demographics to facilitate a melting pot of students with diverse gender, year, and majors. The students were separated into mixed core groups between 6 and 8 members. As the semester progressed, students self-selected subgroup members for different projects and discussions from the mother core group. The size of the subgroups were typically 2-3 students. This was effective at building a sustaining intergroup bonding, the distribution of different areas of expertise, and a cooperative environment. Subgroup activities and projects were also selected to include diverse interest and expertise, such as computer programming skills, art and design, electric circuits and Arduino, and traditional hands-on skills. The attitude and performance of the students significantly improved after the core groups parsing and we will continue this for all future courses.

The DMI class is structured with two hours of lecture accompanied with a two-hour activity section each week. During the weekly 2-hour lectures, all 48 students meet as a cohort. The format of the lecture is sometime traditional and sometimes heavy discussion group work. During this time the cohort discuss aspects of the maker movement, develop common soft and hard skills, realize thought process and mindsets, brainstorm, and develop product commercialization and viability concepts. During this time, we also integrated information literacy and service learning elements through expertise from academic and community partners (one for profit and two non-profit). Our dedicated for-profit community partner speaks about designing and getting products to market.

Our non-profit community partners introduce current problems our community is facing and provide opportunities for students to work on a real life solution. This has been an effective way to engage the students and in turn has led to a number of successful projects. Some of these projects include helping regional homeless, novel trash collectors, vehicle parking aides, and smart packaging for community wineries. Students gain a regional social awareness and to a lesser degree sustainable responsibility. Finally, the SSU library faculty join the course to guide the development of informational resources, the patent process, and how to provide effective elevator pitches.

During the weekly 2-hour activity session, students were divided into two sections of 24 students. The activity sessions were held in the SSU Makerspace. The bulk of the technical skills are learned during the activity sessions. Students are introduced to various digital fabrication equipment and software and utilize the makerspace open hours to tinker and mastering their skills during the week outside of class. During the first half of the semester, we encourage students to open as many doors and skillsets as possible. Starting with Adobe Illustrator for 2D graphic design, students produce logo designs on printers, vinyl cutters, computer numeric controlled (CNC) mills, and laser cutters. We advance 2D design with traditional hand stiches and machine sewing. We finish 2D design with the digital embroidery machine. Often undervalued traditional skills such as sewing and weaving are revisited and recognized as a new tool in the modern technology era as demonstrated by advances in electronic textile and CNC carpentry. Autodesk Tinkercad and Fusion 360 are introduced as 3D modeling software and students are able to print their 3D models on-sight. The SSU Makerspace has a full suite of 3D printers (Lulzbot min and Taz6, Ultimaker 3 Extended, Markforged, and Chocolate printers). The SSU Makerspace has VR modeling and high-resolution digital scanners to support 3D modeling. After 3D skills, students are introduced to electronics and microcontrollers. Traditional electric circuit activities evolve from harvesting working Christmas lights and wiring them up in combination with LEDs in series and parallel connections. This then lends to Arduino micro controllers, breadboarding, and advanced input sensors and output devices. By the end of the first half of the semester, students are familiar with most equipment in the makerspace and ready for their projects during the rest of semester. The skill and mastery levels of students vary for individual. Students quickly figure out what skills and equipment are needed and who is the best person to contact to advance their understanding. All students work with all the skills including computer programming, electronics and art, but each student takes something different. Electric engineering students learn to hand sew and make bags with a sewing machine. Art students learn basic circuits and add blinking lights with an Arduino. Students from diverse background work together to complement each other to learn and complete a common project in a melting pot without border. The students continue to build an original group boardgame and then a new product to address a real world problem.

A recent survey [2] to non-STEM majors shows that 65.3 % of non-computer science majoring students expressed a need for the computer software introductory course. The same survey also showed that students in the humanities and social sciences expressed higher demand and need of beginning level of computer related courses to overcome their burden of completing computer related subject. We find similar attitudes at Sonoma State University with students wanting more hands-on, computer, and technical skills.

With the creation of the DMI course we have created a testbed to student the impact of maker pedagogy at the undergraduate level. Dr. Lyon leads the efforts on evaluating the two primary educational research questions. This includes a pre and post assessment for all students, interviews for targeted subset, and working with WestEd (an external evaluating entity) to evaluate the impact on graduation and STEM major declaration. Lectures and activity sessions were video monitored and recorded for observation, analysis and assessing purpose. These efforts are still in process, however end of the semester confidence surveys provide some significant results. Surveys indicate undeclared and non-STEM majoring students are increasing their interest in STEM and technology. We are preparing students to the modern digital technology era though a technology playground.

	Agree/Strongly Agree	Disagree/strongly disagree
Interested in learning more science and technology.	92.9%	7.1%
Interested in learning how things work.	100%	0%
Interested in learning how to address real world issues.	85.7%	14.3%
Interested in learning how to start my own business.	85.4%	14.6%

Figure 4. After course confidence survey results for 2018 Spring DMI.

CONCLUSION:

SSU has created a new makerspace and makercourse to serve as a testbed for developing new pedagogy and educational efforts. Preliminary results show a strong increase in interest towards science and technology. Student self-identify the skills most important to them gained from the class include 3D fabrication, sewing, working as a group, and creativity. Makerspaces are powerful motivators towards hands-on and STEAM learning. SSU will continue investigating the impacts on students.

[1] https://library.sonoma.edu/makerspace, https://news.sonoma.edu/article/making-future; http://make.sonoma.edu/; https://issuu.com/susankashack/docs/ssu_insights_spring2017; http://radio.krcb.org/post/makerspace-opens-ssu-students-experience-joys-failure-and-creation

[2] J. Nah Computational Thinking Course for Non-computer Science Majors Hawaii University International Conference Proceedings, (2017)