Board 311: Increasing Representation in Engineering Through Makerspace Technologies

Shama Rajan Iyer, Marymount University

I am as Assistant Professor of Engineering, and my background and experience span biomechanics, tissue engineering, muscle physiology, biomaterials, STEM education and outreach. I have been studying the mechanisms of injury and regeneration in skeletal muscle using a cross-disciplinary approach (engineering, biomechanics, molecular biology, and muscle physiology).

Eric J Bubar, Marymount University

I am the founding faculty of the Marymount engineering program in mechanical and biomedical engineering. I also run a 3d printing and design lab researching the creation of assistive tools for individuals with disabilities. In addition I compose grants to

©American Society for Engineering Education, 2024

Increasing Representation in Engineering through Makerspace Technologies

ABSTRACT: The recruitment and retention of diverse students in engineering professions remains a significant challenge in the United States. With support from an Improving Undergraduate STEM Education: Hispanic-Serving Institutions (IUSE HSI Program) NSF grant, Marymount University (MU) is addressing this challenge through Project DREAM (Diversity Recruited into Engineering through Advanced Making). We report here on the first results from Project DREAM. MU has developed and piloted 1) a two-week, immersive summer program on "Maker-Neering" targeting teaching 3D printing/design, arduino programming and VR design to recruit students into a new engineering program and 2) piloted the first semester of an innovative year-long introductory engineering course using low-cost makerspace technologies (including 3D printers, arduino, python programming, and virtual-reality) in project-based experiences to improve foundational engineering skills. We have successfully implemented the two-week summer program and the first semester of the year-long introductory engineering course, where we have seen students complete miniature capstone projects that address genuine community needs including gamifying bionic prosthetic training, producing a machine for recycling bottles into 3D printer filament and designing models for 3D printing muscle tissue. We believe the project's focus on relatively accessible maker technologies will provide a low-cost, practical and accessible model for any educational institution to provide in-demand engineering skills, improve engagement, provide foundational engineering skills to underprepared students, increase STEM opportunities for UR in STEM students, increase collaborations between students, universities and their communities, and improve engagement and retention in STEM for students upon graduation.

INTRODUCTION:

Through the Improving Undergraduate STEM Education: Hispanic-Serving Institutions (IUSE-HSI Program) NSF grant titled "Project DREAM (Diversity Recruited into Engineering through Advanced Making)" Marymount University is developing a project based curriculum utilizing additive manufacturing to 1) improve recruitment of under-represented in STEM students in engineering and 2) improve retention and graduation rates of under-represented in STEM students. To address the first goal, we have designed an immersive summer program in maker-engineering. Students receive college credit for attending a 2 week course from 9 AM- 5 PM where they are taught basic skills in 3D printing/design, arduino/robotics, Python programming and VR design (Table 1).

Table 1. Makeneering Engineering Summer Course Projects

	Fabricate	Design & Program
Week 1: Fidget Spinner	**Students make makercoins & parametric fidget spinners**	**Tinkercad, Codeblocks & Fusion 360**
Week 1: Calibration and 3D Prints	**Students make calibration objects & dogbone 3D prints**	**PrusaSlicer, Curia, Lychee**
Week 1: A Lightshow	**Students make a virtual and physical LED lightshow**	**Tinkercad, Arduino**
Week 2: An Arm in the Making	**Students build an exoskeleton arm**	**Tinkercad, PrusaSlicer, Curia, Lychee, Arduino**
Week 2: SPOT the dog	**Students develop a robotic SPOT dog**	**Building & programming a miniature robotic SPOT dog kit**
Week 2: Gaming & VR	**Students develop a VR game**	**VR game design in Unity**

To address the second goal, we first recognize that many under-represented in STEM students arrive at college without adequate foundational mathematics and physics knowledge. We sought to design a curriculum that would allow our program to help students succeed by leveling up these foundational skill sets. Calculus I, a course with traditionally high DFW rates, saw significant improvements in Marymount student success rates when the math department distributed the course across a full year. Improved success, retention and graduation rates in STEM fields have likewise been observed at other institutions (Kleingbeil & Bourne, 2013) when these types of foundational courses are taught over two semesters. Recognizing this, we designed an introduction to engineering class that spans the first year of the engineering program at MU. This allows us to create a highly interactive, hands-on course that uses low-cost maker-space technologies to provide foundational engineering skills. By spreading the course over two semesters, we are able to intersperse units covering basic skills in Calculus I and Physics 1/2, and how understanding that content translates into more tangible skills. In essence, the introductory engineering course with maker skills serves as a fun and exciting project-based course to maintain student excitement about engineering while also allowing faculty to supplement the “fun” engineering with basic math/physics lessons.

METHODS:

To prepare for data collection, we received an IRB exemption (IRB 814: PROJECT DREAM: Diversity Recruited into Engineering through Advanced Making) on February 13, 2023. Pre (first day of summer program) and post-surveys (last day of summer program) were conducted

for high school students attending the two-week summer program in summer 2023, with both close ended and open ended questions according to IRB approved protocols. In the two week summer program, students participated in a project-based curriculum on modern digital fabrication tools (Makerneering) with projects in 3D design, 3D printing, arduino electronics, robotics and VR game design. The course consisted of highly immersive lessons and projects with meetings lasting M-F from 9AM-5PM for two weeks. External evaluators from the SOAR Evaluation and Policy Center at New Mexico State University provided a summary of the survey data to the research team.

The engineering program at Marymount University started in Fall 2022, a year before the funding from NSF-IUSE was obtained. Some concepts and lessons were developed in this initial year of the program, but formal data collection for the study commenced with the Fall 2023 cohort of students once funding was obtained. Pre-surveys were conducted in the first semester of the yearlong introductory course which introduces students to 3D design, 3D printing, arduino electronics, robotics, and VR game design in a project-based curriculum, with students completing one engineering capstone project in student teams. In the second semester, students further their skills in these areas while completing two engineering capstone projects in student teams. Upon the completion of this second semester, post-survey data will be collected, which will also be analyzed and summarized by the SOAR Evaluation and Policy Center.

RESULTS:

Students participating in the two-week summer program in summer 2023 reported a positive perception of the program, with a common area of interest being the hands-on-projects, including programing for virtual reality game design, 3D design and printing and design, construction and programming of a robotic arm (Figure 1). Participants were from a diverse variety of fields with interests in engineering, computer-science, biology, ecology and nursing. The primary recommended change was increasing the time allocated for the projects for future workshops, in addition to shorter classes with a full session longer than 2 weeks. Participants also recommended increasing the span of these workshops to include projects in other STEM fields, including animal science and nursing. Data collection is underway for the year-long introductory course. Students in the introductory course in fall 2023, and in the pre-study pilot format in 2022-2023 have completed several engineering capstone projects with varied applications such as a submersible for ecological research, 3D printed prosthetics training and, recently, muscle tissue engineering applications.

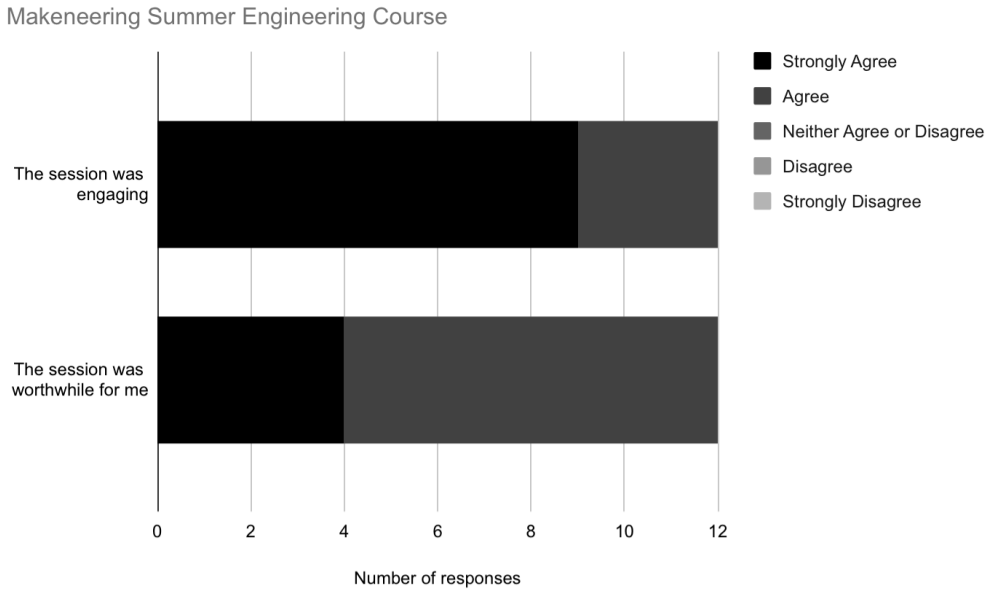

Figure 1. Student evaluations of the project-based makeneering summer session.

CONCLUSIONS:

The positive experience for participants in the two-week summer workshop suggests that makerspace technologies can be readily utilized for improving student learning and student perception of engineering, in addition to improving retention in STEM fields. Furthermore, due to the low cost nature of makerspace technologies and their broad span of applications we see the ability to expand this approach to include workshops, projects and student teams from a wide range of STEM fields, including ecology, environmental science, chemistry, biology and computer science.

The year-long introductory engineering course has been successfully implemented for a full semester, with several successful student capstone projects prior to the project funding period. While we are still collecting information for feedback, it must be noted that the capstone projects have spanned various applications in fields from ecology to tissue engineering, and have engaged students in various STEM disciplines (biology, biochemistry, biomedical engineering and mechanical engineering). We have observed this introductory course to be a cohort building experience and anticipate a largely positive experience, with improving retention rates in not just engineering but in other STEM fields. We plan on fostering student teams with students in various disciplines to expand the scope of capstone projects and develop design projects that provide solutions for authentic community challenges.

REFERENCES:

Klingbeil, N. W., and A. Bourne. 2013. “A National Model for Engineering Mathematics Education: Longitudinal Impact at Wright State University.” *2013 ASEE Annual Conference &*. https://peer.asee.org/a-national-model-for-engineering-mathematics-education-longitudinal-impact-at-wright-state-university.

ACKNOWLEDGEMENTS:

We would like to thank Jennifer Martinez and Rachel Boren Ph.D.at the SOAR Evaluation and Policy Center at New Mexico State University in assessing the feedback received from students in the two-week summer workshop. We also gratefully acknowledge support from NSF IUSE-HSI 2246957 which makes this work possible.