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BOARD # 248: Increasing Students' Confidence in Engineering through Makerspace Technologies: NSF IUSE HSI

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Increasing Students' Confidence in Engineering through Makerspace Technologies: NSF IUSE HSI

ABSTRACT: The lack of adequate foundational engineering skills among many underrepresented in STEM students poses a significant challenge to retaining students in engineering professions. To tackle this challenge, Marymount University (MU) is implementing Project DREAM (Diversity Recruited into Engineering through Advanced Making) through support from the Improving Undergraduate STEM Education: Hispanic-Serving Institutions (IUSE HSI Program) NSF grant. We present the initial findings on student perceptions from a year-long introductory engineering course that employs low-cost makerspace technologies, such as 3D printing, Arduino, Python programming, and virtual reality, in project-based experiences to enhance foundational engineering skills. In the first semester students receive instruction in basic math and physics to supplement those introductory courses as well as comprehensive training in how to use 3D design software, operate 3D printers, program circuits, write basic code in Python and interact within VR environments, culminating in a capstone project experience. In the second semester, students apply these skills in teams to complete two guided capstone-style projects (e.g. 3D printed battle robots, programming AI dogs, fabricating magnetic stirrers and assembling a 3D printed SeaPerch submersible). Overall, students reported a positive experience with significant increases in confidence in areas of teamwork, problem solving, data management, engineering design, data analysis and technical skills. While students' perception of the relationship between the skills developed through this course and themselves as engineering professionals improved through the duration of this course, this perception must be further strengthened. We suggest that this low-cost and accessible model can be utilized by any educational institution to provide in-demand foundational engineering skills to improve engagement and retention of under-represented in STEM students using common makerspace technology.

INTRODUCTION:

Through the use of additive manufacturing, Marymount University has developed a project based curriculum 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, with funding from the Improving Undergraduate STEM Education: Hispanic-Serving Institutions (IUSE-HSI Program) NSF grant titled "Project DREAM (Diversity Recruited into Engineering through Advanced Making)". To achieve the first goal, we have designed and delivered a two week summer bridge program to high school students interested in engineering that utilizes additive manufacturing, Python programming, VR design, etc.

To address the second goal, we have developed a year-long project based course to help students obtain foundational engineering skills through the use of low-cost maker-space technologies (approximately $20,000). We hoped to replicate previously observed student success, and in turn

improve retention and graduation rate in STEM fields, through distribution of core courses (such as Calculus I) over the full year (Kleingbeil & Bourne, 2013). In addition, we also interspersed application of topics in Calculus I and Physics 1/2 in small projects. Examples of hands-on applications include a 3D printed derby race car challenge - to reinforce understanding of the physics and calculus underlying 2D kinematics/inclined plane motion and circuit design with arduino and RC battlebots).

Despite various interventions to increase student retention in engineering, the attrition rate for engineering students is approximately 50%, with the primary attrition occurring in the first year (Flanigan, 2024). One of the factors in this attrition has been identified as confidence (Geisinger & Raman, 2013). We hypothesize that student self-confidence will significantly improve through a project-based course utilizing low-cost, easily accessible maker-space technologies, which could in turn improve student retention rates.

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 course in Fall 2023) and post-surveys (last day of course in Spring 2024) were conducted for students enrolled in ENGR 101 and BIOE/MENG 102, with both close ended and open ended questions according to IRB approved protocols.

In the first semester, students completed one engineering capstone project, with smaller projects throughout the semester geared towards learning 3D design, 3D printing, arduino electronics, robotics, and VR game design. In the second semester, students completed two engineering capstone projects in teams, with smaller projects to provide refreshes of materials taught in ENGR 101. 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.

Close ended and open ended questions included pre and post surveys of perceiving student proficiency in foundational engineering skills, including perceived perceptions of self-efficacy and self-confidence, student perception of the project-based course, and student feedback.

RESULTS:
Data collection is still underway for the year-long introductory course for the second cohort beginning in Fall 2024. Here we are presenting data for the first full year-long introductory course for the cohort beginning in Fall 2023. 20 students completed the pre-survey; 16 students completed the post-survey. Students have completed various capstone projects, with a wide breadth of topic areas in diverse fields ranging from tissue engineering (bioprinting skeletal muscle), ecology (development of a submersible for ecological research), rehabilitation (3D printed prosthetics) and construction (3d printing with concrete/chocolate) among others.

Students reported increased confidence in using technical STEM tools (such as use of tools, instruments and/or techniques), creating STEM design drawings identifying an engineering design problem to solve and solving a problem as a part of a team(Figures 1-4). Students reported increased confidence in their perception of themselves as a STEM professional, although this could be further strengthened (Figure 5). For this initial cohort, freshmen to sophomore retention was approximately 80%. Data collection, including retention data collection, is still underway.

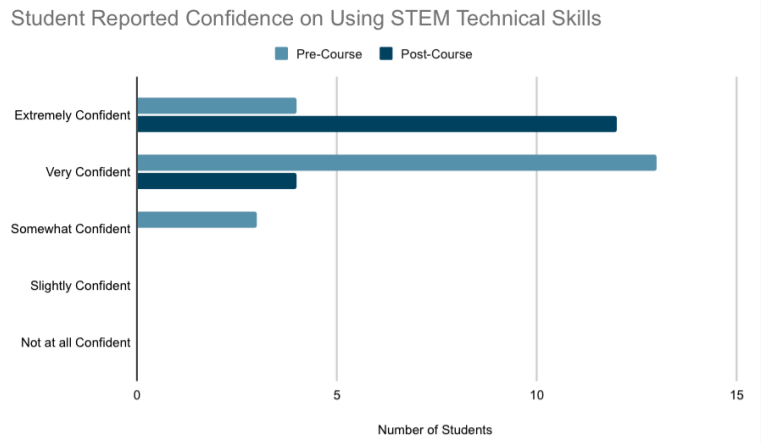

Figure 1. Students reported confidence to the statement "Using technical STEM (Science, Technology, Engineering, and Math) skills (use of tools, instruments, and/or techniques)".

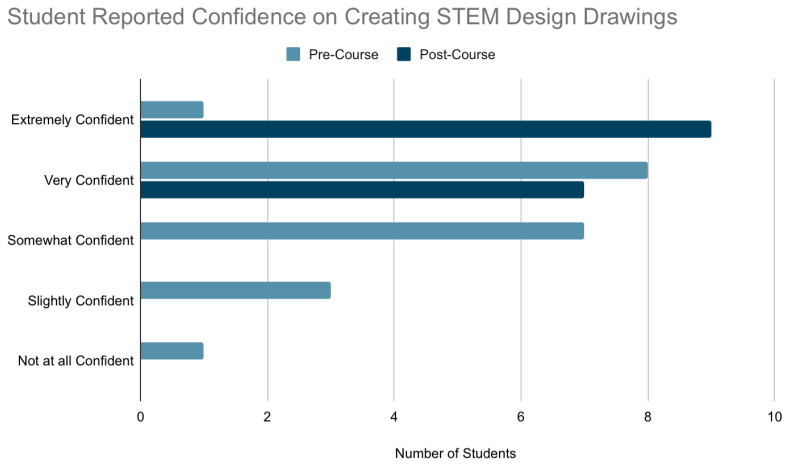

Figure 2. Students reported confidence to the statement "creating STEM (Science, Technology, Engineering, and Math) design drawings".

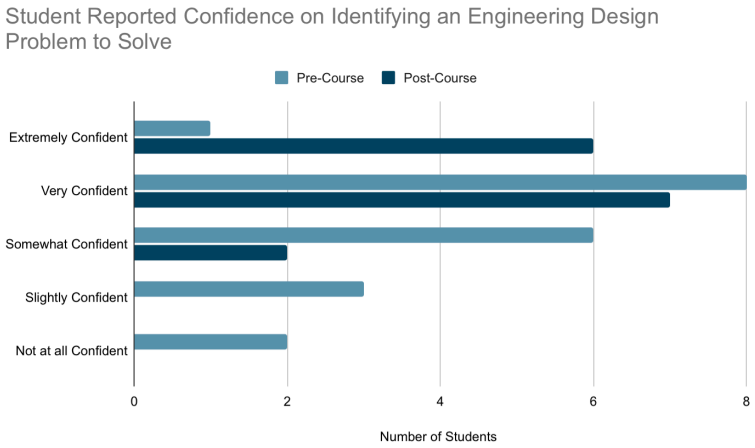

Figure 3. Students reported confidence to the statement "Identifying an engineering design problem to solve".

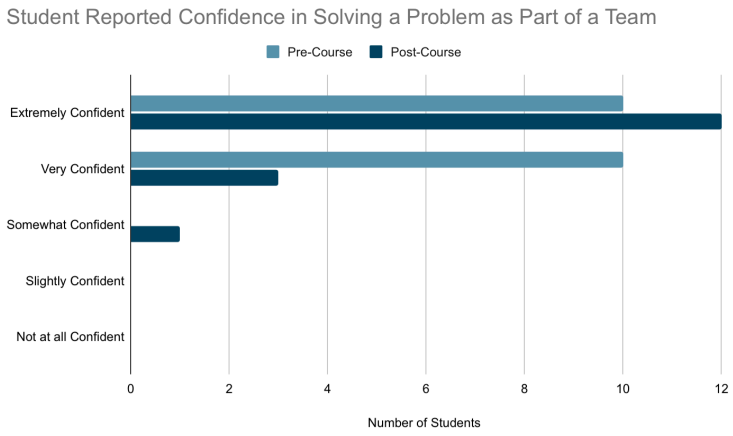

Figure 4. Students reported confidence to the statement "Solving a problem as part of a team".

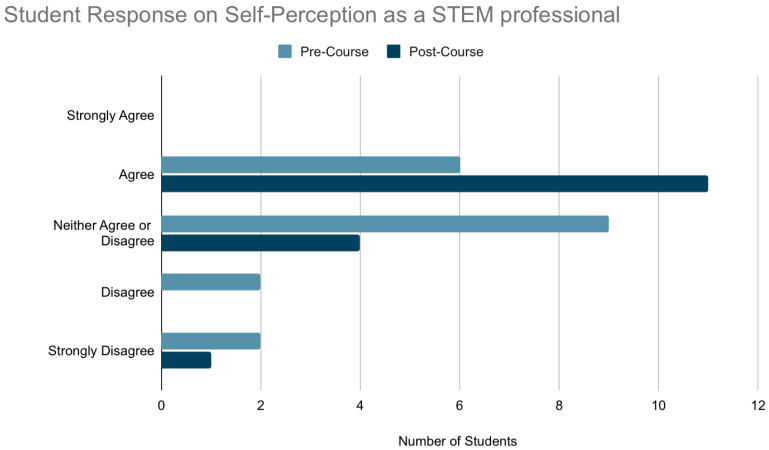

Figure 5. Student responses to the statement "I have come to think of myself as a STEM professional".

CONCLUSIONS:

Overall, students had a positive experience in the year-long foundational course, with high student satisfaction regarding the hands-on-projects, and improving student confidence in understanding of STEM methods. However, there remains room for improvement in encouraging students' perception of themselves as STEM professionals, which although improved significantly by the course, could be improved further. We are currently working on strategies to strengthen the relationship between the foundational engineering skills being acquired though the capstone projects and an engineer completing a project. Although the freshmen to sophomore retention in engineering at 80% is below our intended goal of 90%, it is greater than the average attrition in engineering at 50% (Flanigan, 2024). Data collection is ongoing for the Fall 2024 cohort, including assessment of retention rates. Overall, this project-based curriculum to improve foundational engineering skills can be easily adapted and implemented at any institution due to the low-cost and highly accessible nature of makerspace technologies.

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