Applying Entrepreneurially Minded Learning to the Design and Fabrication of Soft Robotic Fish with Native American Engineering Students.

Dr. Monsuru O. Ramoni, Navajo Technical University

Monsuru Ramoni is an Associate Professor of Industrial Engineering at Navajo Technical University, Crownpoint, NM. He has M.S. degrees in Manufacturing Engineering and Management and Industrial Engineering from the University of Birmingham, United Kingdom, and Wayne State University, Detroit, Michigan, respectively. He received his Ph.D. in Industrial Engineering from Texas Tech University, Lubbock. His research focuses on additive manufacturing, material characterizations, and engineering education. Dr. Ramoni leads various STEM outreach activities in Native American communities. Dr. Ramoni has received funding from NASA, DOE, and USDA and published in high-impact journals.

Jonathon Chinana

Jonathon Chinana is a Navajo from Cuba, New Mexico. He is in B.S. Electrical Engineering at Navajo Technical University. He has interned at The Materials Research Science and Engineering Center (MRSEC) at Harvard University. He presented posters on some of his undergraduate research at conferences.

Mr. Ty Shurley, Navajo Technical University

My name is Ty K. Shurley. I am 27 years old and Native American. My tribe affiliation is Navajo, and I'm from Hunters Point, Arizona. I love drafting and designing, my drawings have always helped me to define who I am as a person and what I am capable of doing. I have my own unique way of being creative and at the same time dealing with problem solving. I also have highly developed technical skills. These are some of the reasons why I am so passionate about becoming an engineer. I have my Pre-Engineering, Associate of Science and Computer Aided Drafting & Design certificate. I received my degree and certificate back in April 2019 at Southwestern Indian Polytechnic Institute. I am currently enrolled at Navajo Technical University. I attended the graduation ceremony for my associates degree for Mathematics back in May 2022. Now I am enrolled in the bachelor's program for Mechanical Engineering here at NTU.

Dr. Kathryn Hollar, Harvard John A. Paulson School of Engineering & Applied Sciences

Kathryn Hollar grew up in rural North Carolina, and attended North Carolina State University, majoring in Chemical Engineering and English. The first person in her family to obtain a bachelor's degree, she continued on to a Ph.D. in Chemical and Biomolecular Engineering at Cornell University, specializing in reactor conditions for recombinant protein production. She received her degree in 2001, and began a faculty position in engineering at Rowan University in New Jersey, where she taught freshman and sophomore engineering design, as well as fluid mechanics and bioprocess engineering.

She began her position as Director of Community Programs and Diversity Outreach at the Harvard John A. Paulson School of Engineering and Applied Sciences in 2003. In partnership with faculty, postdoctoral fellows, and graduate students, she develops and implements programs for K-12 students, teachers, undergraduates, and families that are designed to increase scientific and engineering literacy, and to inspire people with diverse backgrounds to pursue science and engineering careers. At the undergraduate level, she directs a Research Experiences for Undergraduates program that brings students to Harvard for 10 weeks to work in research laboratories. This program hosts between 45-70 students per year, and recruits from diverse institutions, including community colleges, tribal colleges, historically black colleges and universities, and Hispanic-serving institutions. The program focuses on providing research opportunities for students who are underrepresented in science and engineering careers in the United States, including students with disabilities, military veterans, Native American (indigenous) students, LatinX students, Black/African American students, women, and students who are the first in their families to attend college.

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ABSTRACT

Engineering students have limited opportunities for experiential learning, especially at Tribal Colleges and Universities, where engineering programs tend to be small, and resources are extremely limited. Typically, the first and senior years of a student's engineering education journey are infused with hands-on projects and capstone courses. However, the sophomore and junior years generally need more opportunities for active learning, gaining professional skills, and developing a sense of professional practice. Also, scholars have increasingly realized that arts subjects help students understand connections between different disciplines from a comprehensive perspective.

This study highlights findings from integrating entrepreneurially minded experiential STEAM learning into a second-year engineering course - Design & Manufacturing Processes I. A total of six students enrolled in the course. The project required students to develop engineering activities to highlight water pollution via the design, fabrication, and programming of soft robotic fish. During one semester, students formed teams to work on project tasks, including sketching out a fish, designing a mold (fish) in Solidworks, 3D-Printing the mold, fabricating the fish (pouring silicone into the mold), testing the fabricated fish, programming the fish for blinking light and vibrations. A metacognitive photovoice reflection was used to assess the project's impacts. The preliminary thematic analysis highlights three major themes of ABET learning outcomes as follows: (1) the ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics (2) the ability to function effectively on a team (3) the ability to acquire and apply new knowledge as needed, using appropriate learning strategies. The paper includes details related to the intervention and lessons learned so other engineering instructors, especially in Native American serving schools, can easily re-create in the classroom.

1. Introduction

Native Americans are underrepresented in Science, Technology, Engineering, and Mathematics (STEM) fields. Native Americans comprise nearly 2.9% of the population (United States Census, 2020), and they represent only 0.25% of all engineering bachelor's degree recipients (Fig.1), 0.3% of the U.S. engineering workforce(Fig.2), and 0.07% of all engineering faculty (Fig.3) [1, 2, 3].

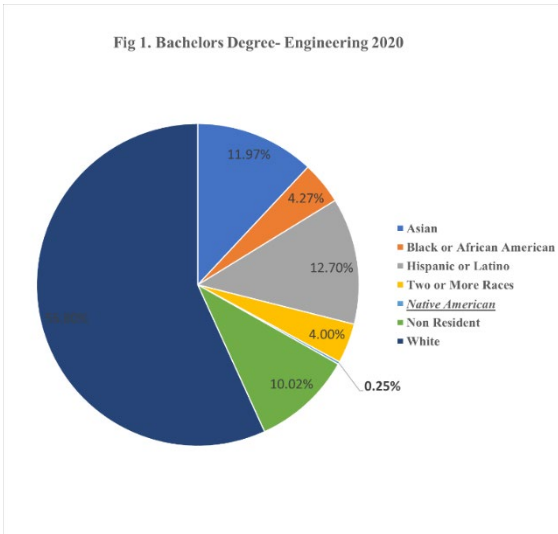


Fig 1. Bachelors Degree- Engineering 2020

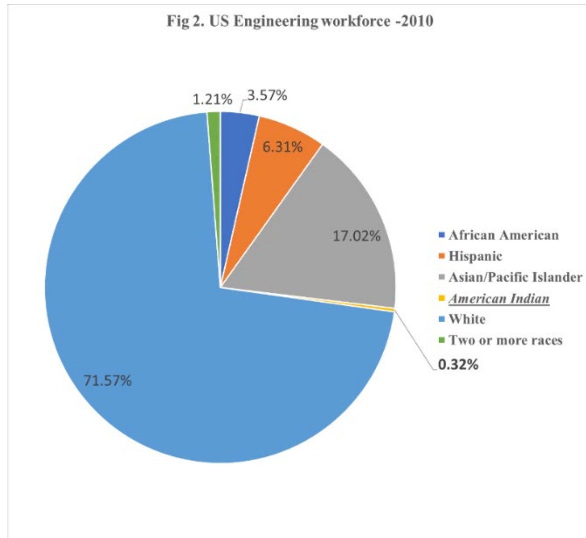


Fig 2. US Engineering workforce -2010

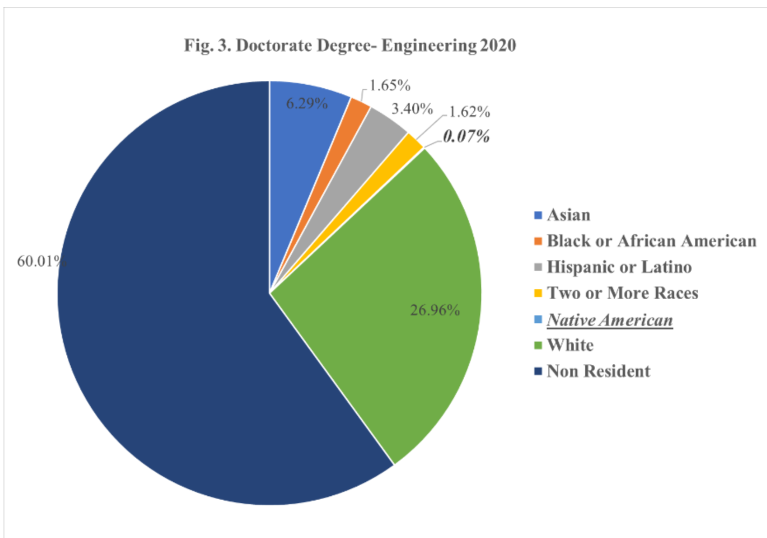


Fig. 3. Doctorate Degree- Engineering 2020

In 2020, 54 of 46,082 STEM doctoral degrees awarded were granted to Native Americans [1, 4]. Only 8 out of 10,890 engineering Ph.D. who graduated in 2020 were Native Americans [4, 5]. While challenging, increasing the number of Native Americans with engineering degrees, which is advantageous to the creativity and productivity of the U.S. engineering workforce. Native Americans offer a unique perspective into engineering challenges due to the fact that Native American peoples had and still have men and women with highly developed specialized skills; extensive, intimate knowledge about the movement of the heavenly bodies; the chemical qualities of plants; and the medicinal applications of animal and botanical matter.

Intervention efforts such as scholarships to Native American students, the National Science Foundation Tribal Colleges and Universities Program (TCUP), NASA Minority University Research and Education Project (MUREP) for American Indian and Alaska Native Science, Technology, Engineering, and Mathematics (STEM) Engagement (MAIANSE) provide support to design, implement and assess comprehensive institutional improvements in STEM education and research capacity at TCUP-eligible institutions of higher education. However, there are reasons, apart from the prevalent poverty, responsible for underrepresentation, especially in engineering: these include a lack of well-studied and documented interventions for Native American in higher education; limited comprehensive studies on recruitment and retention of

Native American students in higher education; and a dearth of culturally relevant and culturally informed engineering curricula in STEM.

Native American students have the lowest rate of STEM degree persistence compared to other groups [6] due to the STEM cultural values being particularly individualistic, individualistic, rather than community-motivated [7, 8].

Many Native American cultures strongly emphasize the connectedness of people and the environment [10]; however, particularly in engineering degree programs, early coursework does not emphasize the connectedness of people and the environment [8, 9]. Therefore, Native American students who may not see/engage in this aspect may be particularly at risk of losing motivation for - and possibly leaving - their engineering majors [1]. These issues contribute to low Native American representation and deprive the U.S. of an opportunity to increase diversity to solve better engineering problems and design innovative solutions that benefit more people [11].

A 2012 study from Lesley University indicates Arts integration in STEM stimulates deep learning and increases student engagement among minority students [12, 13]. STEAM education evolved from STEM, which has several different features and benefits. Primarily, its primary benefit is science-oriented training with an emphasis on creativity. STEAM learning is an approach that emphasizes students' expressions and creativity in solving technical or science-related problems. STEAM approaches can help students learn skills relevant to the 21st century, including innovation and cultural sensitivity [9, 10].

A more advantageous STEM + Arts (STEAM) approach to engineering education is proposed to support inclusive education for minority students. This study aims to develop culturally relevant engineering coursework and of high value to Native American communities, showing the connectedness of people and the environment, to attract and retain Native American students in engineering.

The engineering coursework involves a hands-on STEAM project to provide Native American students an opportunity to see the connectedness of people and environment in engineering and become motivated to graduate with knowledge of engineering design and processes, creative thinking, and teamwork. The coursework is also enhanced with project activities that offer entrepreneurship learning to increase awareness among Native American students.

2. Literature Review

Engineering plays a central role in designing technologies, systems, and services that address human needs and wants. Diversity in engineering helps enrich engineering innovations as every culture sees the world differently. Minority groups are underrepresented in the U.S. engineering workforce. Native Americans are among the most under-represented in engineering in the United States [11, 12]. Scholarships and other intervention efforts have not been very effective, as demonstrated by the level of Native American undergraduate enrollment, which has decreased over the last three years compared to other groups [13]. To broaden participation in engineering, there is a need for new thinking to engage this population by making engineering education culturally relevant to Native American students to increase retention and completion of engineering degrees.

Native Americans have always been accomplished scientists and innovators in ways that value balance and unity with the environment [7, 10 -13]. Engineering education programs need to include aspects of Native Americans' harmony and unity with the environment in the curriculum via bio-inspired design. Native Americans have always placed value on the natural world. The natural world contains infinite examples of how to achieve complex behaviors and applications by cleverly using simple materials, as all organisms use limited raw materials to survive. Bio-inspired design [14] involves learning concepts from the natural world and applying them to the design of real-world engineered systems.
Robotics has a track record of engaging students in engineering [15]. Combining bio-inspired design with robotics offers an integrated approach (soft robotics) to teaching engineering to Native American students in a culturally aligned and engaging learning space. This soft robotics approach also allows exploring how natural assets can support innovation, deepening the need for interdependence between academic disciplines with cross-disciplinary connections between the arts, science, and engineering (STEAM).

Besides enhancing engineering education, soft robotics encourages students to discover, evaluate, and exploit opportunities through engineering principles and design. Soft robotics [16] is a growing field with applications – medicine, agriculture, and STEAM learning kits that students could see the potential for entrepreneurship opportunities.

The evaluation of the effects of integrating soft robotics on Native American students has been done via participatory action research of photovoice reflections. Photovoice reflection is an arts-based, visual research methodology. The method requires research participants to capture a photographic response to specific questions and prompts. Participants choose photographs or images to describe their experience of issues and explore the reasons that have guided their chosen images. Herbert, Ward, and Latz [17]; Jehangir et al. [18] used photovoice and photoelicitation to explore the needs of new and incoming community college students using a first-year seminar course requiring students to document their needs using photos and words. O'Neill and McMahon [19] used photovoice to improve student feedback toward the evaluation and assessment of an undergraduate physiotherapy degree; group consensus was deployed to recommend solutions and actions. Kelly et al. [20] used photovoice to investigate barriers to cross-cultural instruction where students actively participated by collecting images and documenting interpretations; the results suggested an increase in interest, engagement, and enthusiasm for the course. Bosman, Chelberg, and Couteil [21]used photovoice to enhance mentoring for minority pre-engineering students. Bosman Naeem and Padumadasa [22] used photovoice to derive students' needs for entrepreneurship learning during emergency situations.
During this process, specific constraints are balanced with the achievement of customers' goals and requirements [23] providing an opportunity for students to engage in entrepreneurship.
This project welds bioinspired design, STEAM, and the entrepreneurial mindset together to broaden the participation of Native Americans in Engineering. Students learned to use technical tools and education to develop objects of economic value and thus engage in entrepreneurship learning.

3. Methods

3.1Project design

The focus of this paper is a class project for students in a second-year Industrial Engineering course, IE 223 Design & Manufacturing Processes I. It is a semester-long project in which students form teams to work on project tasks: sketch out a fish, design a mold (fish) in Solidworks, 3D Print the mold, fabricate the fish (pouring silicone into the mold), test the fabricated fish, program the fish for - blinking light, vibrations, and motion, and prepare a bill of materials.

The project tasks are broken down into milestones with due dates (Table 1). Students must submit a report for each milestone, including pictures of the objects.

Table 1. Project Milestone, Due Date and Deliverable

Milestone	**Deliverable**	Due Date
Milestone 1	1 . Team o Students form teams of 2-3. o Each team does a rough sketch of the fish (Fig.4). The rough sketch has no dimensions; the drawing on plain white paper looks close enough to the part of their drawings. Each sketch of a part must have at least 2 views, for instance, top and side views, on a single plain white sheet with the following information. 1. Fish name 2. Team – students' names 3. Rough drawing of fish	Week 3
Milestone 2	Research and design of a mold for fish (Fig. 5) o Conduct online research related to molds for fabrication. Each team does a rough sketch of the Mold for fish fabrication. o Once the team completes the rough draft, they must present it. Each student in the group takes turns speaking about each work	Week 5
Milestone 3	Design Fish Mold in Solidworks (Fig. 6) o Provide an Isometric view and Top view of your SolidWorks model of the Mold o 3D Print (MakerBot Replicator) of the designed mold (Fig.7) (submit pictures of the 3D printed mold by November 3, 2022)	Week 8

Milestones 4	Fabrication of soft robotic fish (Fig.8 a, b) o Pouring of silicone (Smooth-on Mold Star 19T) to fish mold o Submit your pictures of the fabricated soft robotic fish.	Week 10
Milestones 5	Circuitry design and electric components- L.E.D., breadboard, battery, On/Off switch (Fig.9 a, b, c) o Submit your pictures of the assembled electronics with L.E.D. on	Week 13
Milestones 6	Insert electronics in the soft robotic fish(Fig.10 a, b) o Test the soft robotic fish blinking L.E.D. Submit a fully L.E.D. blinking soft robotic fish.	Week 14

Milestone 2 -Fish Sketch, Mold Sketch

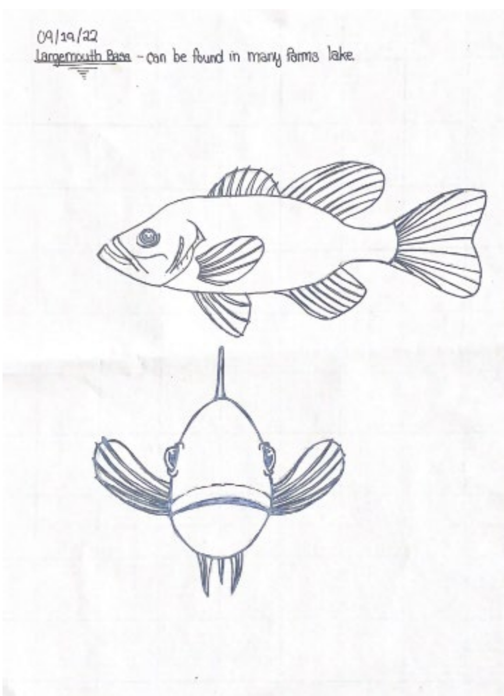


Fig. 4

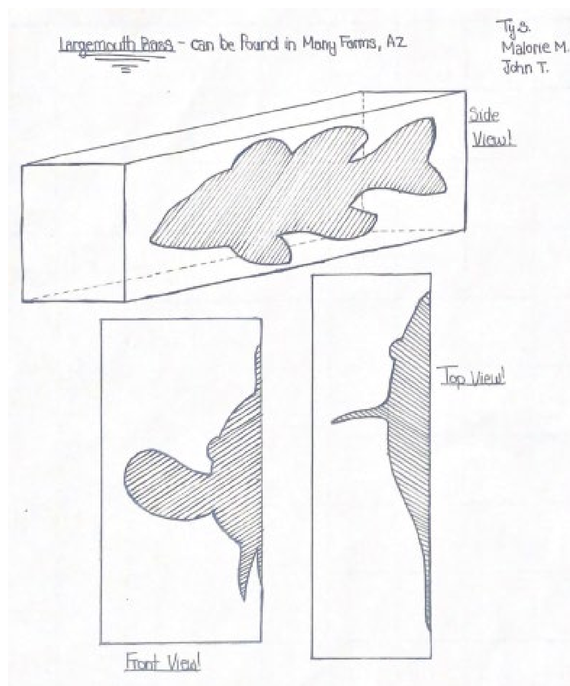


Fig. 5

Milestone 3 - Solidwork Model of Mold, 3D-Printed Mold

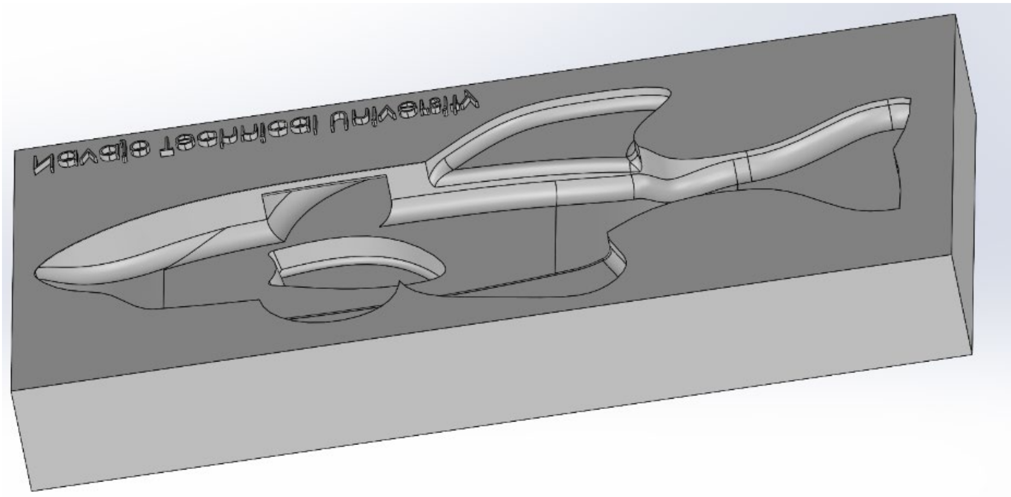


Fig. 6

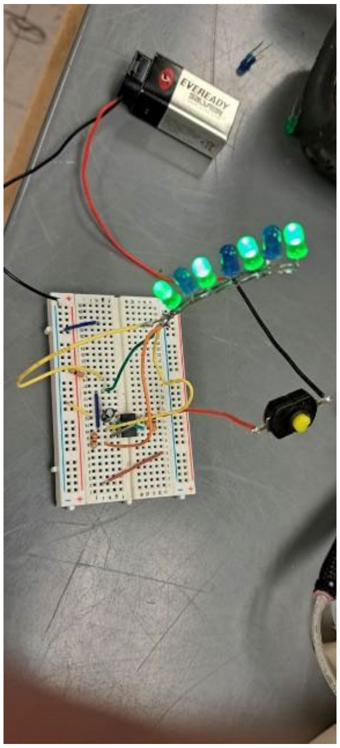
Fig.7

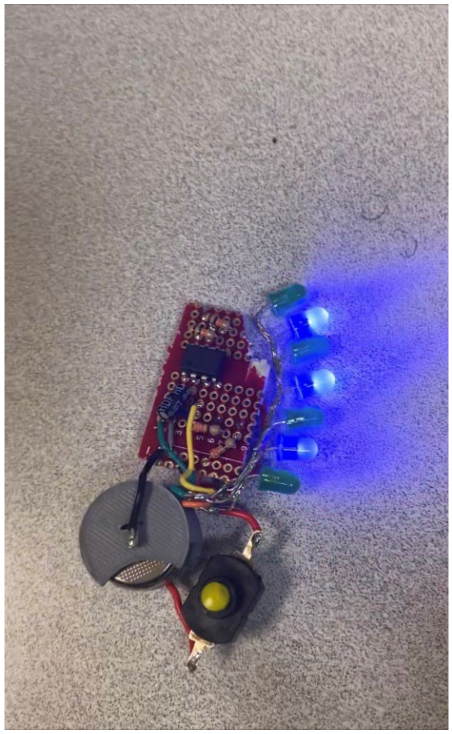
Milestone 4 - Silicone Mold, Fish Mold

Fig 8(a)

Fig. 8(b)

Milestone 5 - LED Circuity Assembly,with ON/OFF Switch





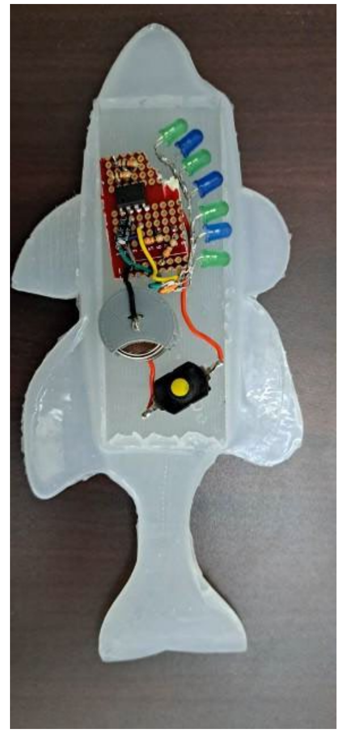
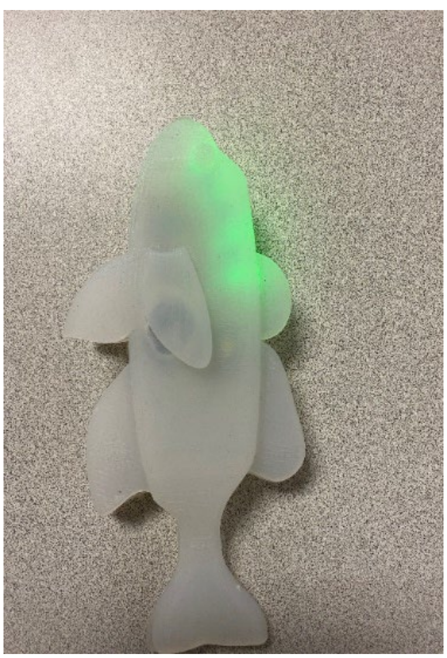


Fig. 9 (a) Fig. 9(b) Fig 9.(c)

Milestone 6- Robotic Fish with LED



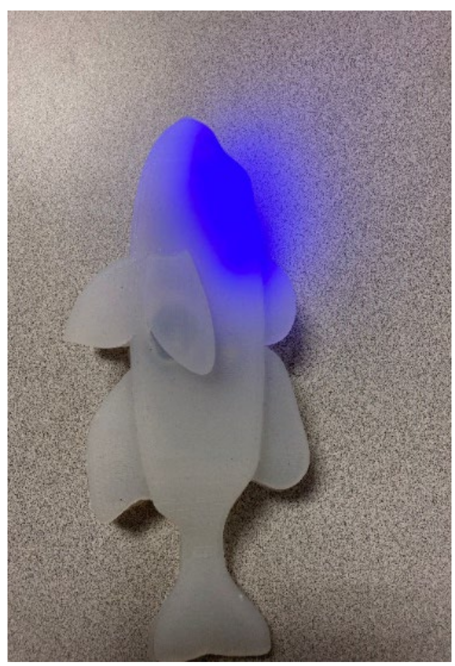


Fig. 10 (a) Fig. 10(b)

The project provides students opportunities to iterate designs with features people want to see in the fish. Students engaged in prototyping and working within the manufacturing constraints of printers to design a mold to specific dimensions. Design iterations, prototyping, and working within constraints are critical elements of entrepreneurship learning. Students also integrate art into the design to create an organic shape of fish and craftily shape the fins and tail into the mold to get fish features.

3.2 Participants

The participants were students in an Industrial Engineering course at a tribal university with ABET Accredited Engineering programs. Six students participated in the course, consisting of five males and one female, aged 20- 36.

3.3 Data Collection Instrument(s)

The results were collected using a metacognitive reflection assignment consisting of two sections, Part 1 - Photovoice Reflection Prompts and Part 2 - Open-Ended Reflection Questions, with three questions in each area. Each student received a Metacognitive Reflection Assessment with Part 1- Photovoice Reflection Prompts and Part 2 - Open-Ended Reflection Questions to provide photographic responses to specific questions and prompts and a narrative of challenges they faced and learned outcomes they gained.
Part 1 - Photovoice Reflection Prompts for conceptual interaction essay as follows: (unclear how these are used)
1. The entrepreneurial mindset is defined as "the inclination to discover, evaluate, and exploit opportunities." Explain how participating in the newly developed curriculum incorporated the entrepreneurial mindset, and lessons learned relevant to the entrepreneurial mindset.

2. STEAM (science, technology, engineering, arts, math) goes one step beyond the well-known STEM to acknowledge the importance of integrating the arts and humanities into more analytical coursework such as that found within engineering. Art can be incorporated through pieces, processes, and movements. Explain how participating in the newly developed curriculum included STEAM (specifically, the arts), and lessons learned relevant to STEAM (specifically, the arts).

3. Bio-inspired design uses the nature-focused context of sustainability, security, and/or biomedicine and health outcomes to motivate analogical thinking and improve the engineering design process. Explain how participating in the newly developed curriculum incorporated bio-inspired design and lessons learned relevant to bio-inspired design.

Part 2 - Open-Ended Reflection Prompts for module reflection essay as follows: (how were these implemented?)

1. The interdisciplinary approach of integrating the entrepreneurial mindset, STEAM (specifically, the arts), and bio-inspired design has been shown to improve student engagement,

motivation, and learning outcomes. How did this interdisciplinary learning experience affect your ability to engage with the newly developed curriculum?

2. What went well? What didn't go so well? What will you do differently next time?

3. What skills did you learn? Please consider both professional skills (e.g., communication, collaboration, etc…) and context-specific skills (e.g., topic area). Why are these skills important for engineers in the real world?

3.4 Data Analysis Procedure(s)

Analyzing the qualitative data of metacognitive reflection determined project impacts and ABET students' learning outcomes. The three most prominent themes were selected for discussion as related to ABET students' learning outcomes [24], and direct quotes are included with this analysis to allow the reader to judge the conclusions drawn by the authors independently.

4. Results

Three outcomes were identified by analyzing the qualitative data to determine the prevalent themes or outcomes across the data set. These outcomes align with ABET students' learning outcomes [24] of a four-year engineering bachelor's degree.

These learning outcomes are (1) **ABET Outcome 1:** an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics (2) **ABET Outcome 5:** an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives (3) **ABET Outcome 7:** an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

ABET Outcome 1 - an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

Student #1 - "Inspired design features and processes has always ***intrigued my mind to understand*** *and also* ***motivated my thinking on how nature*** *can be used to design a well-suited object or building for a specific area or item that is needed such as prosthetics"*

Student #2 - "After the planning process I needed to ***do my research and see what materials and design would be most effective for my project****. I needed to know what I was using to create the fish and how I would add the Arduino to the inside so I can make it like an educational toy. Lastly,* ***I had to think about the end product and evaluate if my decisions*** *in the planning process were effective or not"*

Student #3 -"Sustainable architecture is inspired by the objects or organisms that are native to a specific region, many organisms and plants have been around for centuries and have adapted to its surroundings. For instance, air flow ventilation design within a building or air flow outside of a building due to high wind. Steel structures such as recently built skyscrapers have designs that *replicate organism's exoskeleton that live in the ocean, the design helps disperse fluids around a tower more easily than traditional designs"*

Student #4 -"Learning ***the process and material*** *used to construct a mold was something that I learned from this project"*

ABET Outcome 5 - an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

Student #1 - "What ***I learned*** *from this project was building better communication skills,* ***team decision-making****, designing", "****We worked very well as a team*** *we exchanged contact information so that we could have better communication."*

Student #2 "Everyone had different backgrounds and skillsets which we applied to our project", "Reflecting on the project submittals, I think ***that our team worked well and integrated all the photovoice*** *to complete the project."*

Student #3 - I learned that teamwork and communication is key. When everyone communicates and voices their opinions it makes things a lot easier for the whole team, so we know what to do", "As the project progressed, we were able to talk more and ***I got to know my team more and got acquainted with them, which made the project flow nicely"***

Student #4 –"So, in the program all the young bright students learn to work together to create to benefit mankind"

ABET Outcome 7 - an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Student #1 - "Bio-inspired leg design captures the inner working of the fish design, ***at the completion the***
fish design will have a mechanism within to assist with moving, like the bio-inspired leg*, linkages will be*
operating the movement of the object
Student #2 - "The integration of all three photovoice has never crossed my mind until now, the word photovoice was ***interesting enough for me to do my research as*** *I have no clue what it was"*

Student #2 –"Last semester I built a keyless lock with Arduino and built it with the kit they provide now to make a fish that moves will be a challenge but it can be done"

Student #4 – "This ***project helped with my entrepreneurial mindset*** *because I had to think about how I wanted to make my design, how I wanted it to look, what it would be used for and its purpose"*

5. Discussion

5.1 Theoretical Interpretation

Koedinger sees three main areas of learning engineering, which gives flight to the learner [25, 26]. One of the three areas is motivation -the fuel that keeps students pushing forward when students get stuck on challenging material. Research on Native American students navigating the multiple worlds between home and university further draws attention to persistence factors and barriers that influence Native American students, especially in engineering. One such factor is to "give back" to the tribal community [11, 27], especially in preserving the community's natural environment. Native American students are motivated to succeed and desire to contribute something meaningful to their communities.

The project findings provide evidence of motivation and improved student satisfaction needed to retain Native American students in engineering. This project has a strong element of bio-design that can be related to environmental sustainability, thus amplifying Native American students' motivation for engineering education.

5.2 Compare and Contrast

Engineering begins with a problem, need, or desire that suggests an engineering problem that needs to be solved [28]. Engineering education aims not only to teach students scientific, mathematical, and technical knowledge but also to develop students' abilities to apply such knowledge to solve engineering problems. However, in traditional passive, lecture-based instruction, there is little dialogue between the lecturer and the student. It is difficult to tell if students are learning and if they can apply the knowledge to solve real-world problems. This issue is more pronounced with Native American students, who are generally quiet in the classroom [29, 30, 31] given their cultural upbringing. In contrast, this project facilitates strong instructor and student communication. The findings indicate that the project encouraged students' verbal expressions of thoughts and active interactions between the students and the instructor.

Engineering education tends to place more emphasis on theory over hands-on experiences and promotes competitive learning environments. Past research has indicated that Native American students are more visual and experiential learners, need to feel competent before engaging in a learning activity and prefer cooperative rather than competitive learning environments [32, 12]. The project provides evidence of improved interactions among the students, a better understanding of the engineering process, and improved engineering skills for the students.

The findings indicate that the bio-design infused with experiential learning facilitated improved Native American students' engagement and learning outcomes. Studies demonstrate the benefits of moving beyond traditional lecture-driven approaches in favor of "active learning - experiential learning [12], putting students more in the driver's seat through hands-on projects to engage students and deepen understanding. Studies indicate active learning techniques, in contrast to traditional lecture-driven learning, narrow achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math [12]. It is necessary to incorporate 'learning through reflection on doing and real-world experience in the curriculum [33] to produce better-prepared graduates of diverse backgrounds.

STEM + Art approach utilizes the arts to help students have more access points for guiding student inquiry and critical and interdisciplinary thinking. Students can make connections and solve problems using various methods creatively and collaboratively, as reflected in this project as students use parametric modeling to design organic objects creatively. Mold design iterations and prototyping via 3D printing enable the students to engage in the project and product development methods. The student learned entrepreneurial knowledge of designing, building, and testing products to meet customers' requirements.

5.3 Implications for Practitioners

Among the lessons learned are that engineering educators need to develop a culturally responsive curriculum and facilitate experiential learning to develop students' capabilities of solving real-world problems and improve the retention of minority groups in engineering.

This project has the entire engineering process, from concept to design to build. The project amplifies that it is viable for engineering instructors to have a semester-long class project in a junior year with an entire engineering process, from concept to design to build. Engineering instructors are to have all materials (software, 3D printer, electronics, etc.) for the project available in the lab at the beginning of the semester and be ready to make purchases within a week of students' request. The instructors must create project milestones with due dates and a Gantt chart for the students to follow up. The instructors, at every opportunity, should encourage students to engage in discussions between themselves and have students schedule meetings and milestones due dates on their calendars.

As the project progressed, a committee report from the National Academies of Sciences, Engineering, and Medicine [34] titled "Infusing Advanced Manufacturing into Undergraduate Engineering Education" was released. The report recommends that "undergraduate engineering education programs should cover the entire engineering process, from concept to design to build - engineering deploys solutions to problems. Thus, the knowledge and practice of advanced manufacturing should be part of the undergraduate engineering education program". This recommendation reinforces the core of this project, engaging students in hands-on projects of concept, design, and fabrication (3-D Printing) as part of their engineering education. Engineering educators need to consciously engage students in the entire engineering process, from concept to design to build.

Students gained knowledge and skills to develop photographic responses to specific questions/ to explore topics for questions. Students learned to provide insight into their own perspectives and values.
Students have indicated gains in their uses of photo invoice reflections- photographic responses, a different way of communicating, which are valuable in achieving ABET students learning outcome #3- an ability to communicate effectively with a range of audiences.

Engineering instructors can include photovoice reflection to engage students in active learning of the application of engineering inquiry, reflection, critical thinking, and different communication styles.

5.4 Limitations and Future Research

The project has limitations; the participant size is one of them. There were six students in the project. The number needed to be higher to confirm that the project with a much bigger engineering class could complete within a semester. Future research should be directed toward replicating this project with a bigger sample size to check for effect on the project completion, resources, and faculty workload.. However, there is still sufficient opportunity for developing new non-traditional (bio-inspired design) projects to endear Native American students to engineering to have a diverse engineering workforce.

6. Conclusion

6.1 Response to Research Question/Objective

There is a need to broaden access to engineering education for minority students to grow a diverse engineering workforce. Changes in the scale and complexity of engineering problems and solutions have re-identified engineering practice and created urgency in rethinking how engineering students are trained for the profession.

This study is guided by research on (1) How Native American students can be supported in the learning of engineering process through curricula that are pivoted on environmental sustainability and experiential learning, (2) the student learning outcomes from Native American engineering students that participated in the design and fabrication of soft robotic fish.

6.2 Summary of Main Takeaway

Diversity increases innovation, creativity, and strategic thinking because teams from different backgrounds can draw upon their unique experiences and a wider range of knowledge to spark new, innovative ideas [11]. Increasing the presence of Native Americans in engineering is advantageous to the creativity and productivity of engineering. Native Americans bring different experiences to the workforce due to their unique cultural practices. This paper contributes to engineering education by highlighting the cultural aspect of the low participation of Native Americans in the engineering program and how engineering education must be broadened to draw and retain Native Americans in engineering through a culturally responsive curriculum.

The paper highlights photovoice reflection as an active learning approach to increase the communication skills of minority students. Engineering instructors can replicate this project as a bio-inspired design to engage students in STEAM learning. The project tasks, milestones, materials, and equipment are documented for replication. Instructors can also use photovoice reflection for the students to communicate their unique perspectives and values. Another contribution of the paper is how faculty can relate the students' photovoice responses and narratives to the ABET student learning outcomes. It also helps to highlight areas for continuous improvement in courses and engineering programs as part of an effort to increase access to engineering.

The paper also highlights the process of engineering minority students hands-on learning engineering process of concept, design, and build in the engineering sophomore and junior years. This process will provide students with authentic engineering experience to stimulate their creativity and curiosity and enable them to gain meta-skills, including leadership, communication, lifelong learning, entrepreneurship, and teamwork.

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