2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
ASEE
Paper ID #37685

Enhancing Programming Industrial Robots Course through Integration of the Entrepreneurial Mindset

Dr. Maged Mikhail, Purdue University Northwest

MAGED B. MIKHAIL, PhD., is Associate Professor, Mechatronics Engineering Technology at Purdue University Northwest. He received his PhD in Electrical Engineering from Tennessee State University, Nashville, Tennessee (2013), M.S., Electrical Engineering, Tennessee State University, Nashville, Tennessee (2009) and B.S., Electrical Engineering, University of El Mina Cairo, Egypt (2001). His dissertation title was "Development of Integrated Decision Fusion Software System For Aircraft Structural Health Monitoring" and thesis title was "Development of Software System for Control and Coordination of Tasks among Mobile Robot and Robotic Arm."

Dr. Khalid H. Tantawi, University of Tennessee at Chattanooga

Dr. Khalid Tantawi is an Assistant Professor of Mechatronics at the University of Tennessee at Chattanooga . He holds a PhD and MSc. in Electrical Engineering from the University of Alabama in Huntsville, and a double MSc. in Aerospace Engineering from the Institut Superieur de l'Aeronautique et de l'Espace and University of Pisa. He served as a Program Evaluator for ABET- ETAC commission, as a trainer for Siemens Technik Akademy, and was the elected chair of the Engineering section of the Tennessee Academy of Science in 2022 and 2017. His research interests include MEMS, Lipid Bilayer Membrane sciences, and advanced manufacturing.

Prof. Jeffrey Ma, Saint Louis University

Dr. Jeff Ma is Associate Professor of Mechanical Engineering at Saint Louis University. Dr. Ma attended KEEN Foundation-funded programs and workshops to learn fundamental pedagogical techniques of EML, ACL, and PBL to instill entrepreneur mindset into engineering students.

.

Enhancing Programming Industrial Robots Course Through Integration of the Entrepreneurial Mindset

Abstract:

Engineering students equipped with an Entrepreneurial Mindset can transform the world and be able to understand the bigger picture, evaluate markets, and learn from mistakes to create value for themselves and others.

The development of engineering students' entrepreneurial mindset is critical to better prepare them for entering a global workforce driven by technological solutions and new product development. Fortunately, the Kern Entrepreneurial Engineering Network (KEEN) has provided resources for higher education engineering programs across the United States to modernize their curriculum through the integration of the entrepreneurial mindset and the 3C's (curiosity, connections, and creating value). However, unfortunately, limited literature is available that highlights the multidisciplinary approach of Experiential Learning (EL), Entrepreneurial Mindset (EM), and real-world application using the entrepreneurially minded curriculum, for engineering and technology courses.

The purpose of this study is to highlight findings and lessons learned because of integrating an entrepreneurially minded interdisciplinary project (including bio-inspired design and STEAM) into the engineering technology classroom. Specifically, curriculum changes were implemented into a course on programming industrial robots (as part of the minor in robotics). This course is designed for teaching technology students how to install, maintain, and work with industrial robots through real-world applications. This course also assists students in discovering the capability of industrial robots to perform many jobs and real-world applications that could be both unsafe and unpleasant to people. The midterm project used to integrate (EM+ Bio + STEAM was given to the students focused on real-world problem-solving and experiential learning opportunities. The students were required to finish this project within four weeks as part of the integration of the new interdisciplinary project (crossing the realms of entrepreneurially minded learning, STEAM, and bio-inspired design), students completed a photovoice metacognitive reflection aimed to understand their perceived learning outcomes. Preliminary thematic analysis conducted on the metacognitive reflections showcases three core patterns within the data. First, students generally highlighted increased engagement and motivation for the newly developed project. Second, students positively noted the opportunity to apply greater amounts of creativity to the newly implemented project. Third, students explained how STEAM was the core component allowing for interdisciplinary understanding within the new project.

1. Introduction

1.1 Problem Identification

As the world moves closer and closer to a global economy, new approaches to problem-solving will be needed more and more. One way to prepare engineering graduates to enter the global workforce and solve complex problems is through experiential learning [1]. Unfortunately, Engineering students have limited opportunities for experiential learning (often limited to freshman-level Introduction to Engineering and senior-level capstone courses). Implementing

.

hands-on real-world application and experiential learning for conducting practical courses in engineering fields is a must and not a selection, The students must be both theoretically and practically empowered for being successful in their future employment including finding job opportunities, doing well in their responsibilities, and being skillful in doing their duties with high quality, being creative along with entrepreneurial abilities. Lacking this opportunity makes students not competitive and unskilled to address the main problems of society once they enter the labor market. Furthermore, students who did have a chance to expose to real-world experience with experiential learning are less confident to be a leader and lack critical thinking about what they are doing [2].

1.2 Proposed Solution (and Research Question)

In response to the problem mentioned above (e.g., limited experiential learning opportunities for engineering students), this study overcomes the gaps by introducing an interdisciplinary approach to experiential learning that integrates the entrepreneurial mindset, bio-inspired design, and STEAM (with a particular focus on the arts) [1].

This new project approach is adding experiential learning to "mid-level" technical courses to show how theory applies to practice and is implemented in real-world applications. An interdisciplinary research project integrating EM, STEAM, and Bio is a creative technique to provide real-world experiential learning to better prepare engineering students for entering the workforce [2].

The guiding research question is as follows: How does the integration of interdisciplinary experiential learning opportunities influence student perceptions of learning and engagement?

2. Literature Review

Experiential learning is an effective engineering education approach in the engineering field that requires the students to be exposed to real occupations, especially practical experiences that are important to the learning and success of students. The advantages of implementing Experiential learning are not limited to [3]:

- Students have a better chance to understand the concept.
- Students have more chances to be more creative.
- Students can engage with real-world applications and problems.
- Students' mistakes become valuable experiences.
- Students can apply the knowledge immediately.
- Promotion of teamwork and communication skills

Many organizations recognize this problem of limited experiential learning opportunities for engineering students and have provided solutions to help overcome the challenge [4]. However, gaps still exist.

First, the National Academy of Engineers has worked with people throughout the world to publish "14 game-changing goals for improving life on the planet" [5]. This offers a great list for engineering instructors to create assignments integrating these grand challenges into the

.

engineering classroom. However, showing instructors how to develop and implement grand challenge-focused assignments is outside the scope of the organization.

Second, many companies offer internships and/or co-ops to students. [6]. These experiences offer students the necessary real-world opportunities to practice engineering tasks under the guidance of a mentor. However, these experiences are often limited to a small subset of students and lack consistency in learning outcomes and program delivery.

Lastly, ABET has several learning outcomes (e.g., 1-5) devoted to ensuring students get experience with design problems before graduating with an engineering degree. Some of these learning outcomes are as follows: (#2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors, (#3) an ability to communicate effectively with a range of audiences, and (#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 [7].

Having standard qualifications for engineering programs is a wonderful concept, however, ABET requires programs to meet the learning outcomes only once throughout the bachelor's degree program. This is a major gap as many programs will stick to the bare minimum as resources continue to be limited for engineering programs.

The experiential learning approach is a pedagogical method to create value in engineering and technology education, which is used as a strategy for developing values. It is a combination of course materials, lab activities, projects, classroom activities, and real-world experiences to create an exciting and engaging engineering course for students. Experiential learning is very important for all types of education, particularly engineering and STEM education. The aim is to blend theoretical concepts from textbooks with practical experience to equip students with the necessary skills to tackle real-world challenges and issues. This approach intends to improve the employability of our engineering graduates. Also, to comprehend the connection between their classroom knowledge and professional practice and have little opportunity to experience the profession into which they are seeking entry. A recent report from the Carnegie Foundation for the Advancement of Teaching [8] examined six US engineering schools and noted a continuing and widespread emphasis on textbook-centric theory over hands-on practice, an approach that discourages many students and largely leaves them unprepared for real-world problems. The lack of experiential learning opportunities does not prepare our students better, there will be a delay between the time of graduation and the time when our graduates can become effective innovators, and the benefit that our profession can bring to society will be minimized. Many engineering students graduate struggle to co-op with the pressure of real-world challenges and reduced self-esteem and self-confidence. In contrast, when we integrate practical-oriented learning methodologies and experiential learning with the curriculum in the class to improve students' creativity and help students to learn from previous experiences and avoid repeating the same mistakes. The common factors leading to a lack of integrating experiential learning [9],

- Lack of faculty experience and techniques

.

- Insufficient educational spaces and equipment
- Not paying attention to parallel and additional experiences
- Insufficient class management by the educators and technicians

Another way to compensate for and overcome the lack of practical experience and hands-on skills is to seek an opportunity for internships or coops. This is a great door for many of the students to gain this experience, however, not all students had the chance to get internships or coops. The major obstacles that hinder students are [10]:

- Students need to work full-time or part-time to be able to continue and finish their education.
- Students had many courses and most of the courses require laboratory time and lots of homework.
- Unpaid or poorly paid internships
- Lack of transportation between work and school limited students on campus jobs, not internships

ABET criterion 5 is" a minimum of 30 semester credit hours (or equivalent) of a combination of college-level mathematics and basic sciences with experimental experience appropriate to the program". The curriculum mentioned a minimum of 30 semester credit hours (or equivalent) of a combination of college-level mathematics and basic sciences with experimental experience appropriate to the program.
a culminating major engineering design experience that 1) incorporates appropriate engineering standards and multiple constraints, and 2) is based on the knowledge and skills acquired in earlier course work.
ABET enforces institutions to integrate curriculum with experimental experience appropriate. the problem with that is one course in all programs can be sufficient to fulfill the ABET requirement.

The solution for all problems is by integrating experiential learning into the curriculum as a backbone of the course through projects or lab activities. Experiential learning is a learning opportunity for both lecturers and students [11]. One way in which this is implemented is by integrating multidisciplinary groups of students working on real-world projects.

The main goal of this paper is to show the integration of bio-inspired design and STEAM (science, technology, engineering, arts, math), entrepreneurial mindset with experiential learning to better prepare engineering students for facing real-world challenges [12].
First, developing students' entrepreneurial mindset in order to help them to seek the opportunity, overcome challenges and solve real-world application problems [13].
The entrepreneurial mindset is a set of skills, knowledge, belief, and thoughts that enable students to identify and make the most of opportunities, overcome and learn from previous mistakes, and succeed in a variety of settings also, driving them to entrepreneurial behavior.
Second, bio-inspired design is techniques and methods that are used to improve human life and increase the safety of the customers and increase the sustainability and security of the workers.

.

The 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 [14].

Third, 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 audio, video, drawing, etc. [15].

The synergistic way of combining STEAM with bio-inspired design and the entrepreneurial mindset with an experiential learning approach will bring many advantages to the students over the traditional way.

Methods

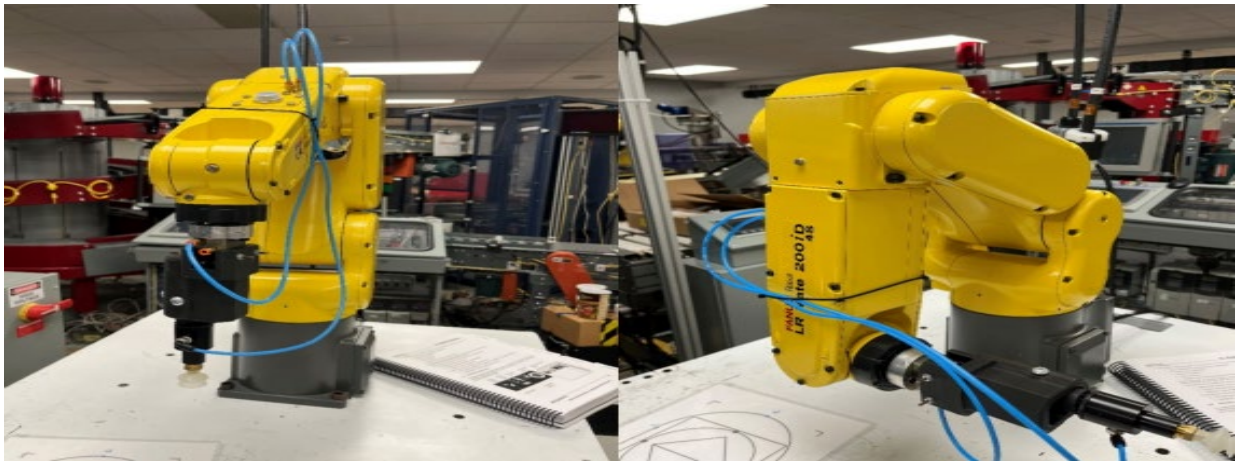


Figure 1. Fanuc Robot LR Mate 200iD

The current maximum offered to students is limited due to the high cost of robots, limited available space, and a shortage of trained personnel. With roughly 20 students per semester, the hands-on programming aspect of the course requires much strategizing upfront to ensure learning gains for all students. In this course, students are required to conduct two projects, one for the midterm and one for the final. This year the midterm project was implemented and conducted differently using a new approach.

3.1 **Study Design**

the "Programming Industrial Robots" course, offered at XYZ, has only four FANUC LR Mate 200iD/4S robots as shown in Figure 1. The Fall 2022 Programming Industrial Robot course explored the opportunity for integrating EM + Bio + STEAM through a course project to enhance the experiential learning for the students to be able to solve a real-world application. The assignment was introduced to the students explaining the main components:

- Discussing the goal and objectives of this project
- Introduced the concept of EM and how students can incorporate it into the project.

.

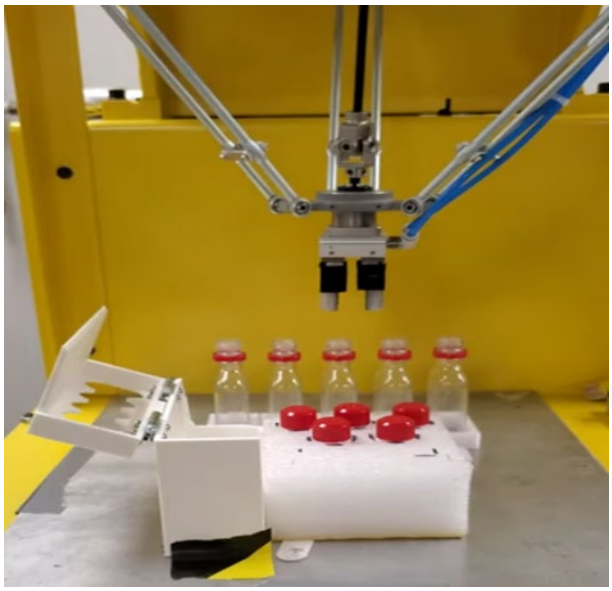
- Introduced and explained how students in the project incorporated STEAM, specifically arts.
- Explained how participating in the project incorporated bio-inspired design.
- Introduced the concept of experiential learning using real-world applications and projects.
- Integration between EL and (EM+Bio+STEAM).
- Explained the photovoice reflection assignment.

This robotics project has a three-phase deployment plan and the goal to actively engage students as shown in Table 1.

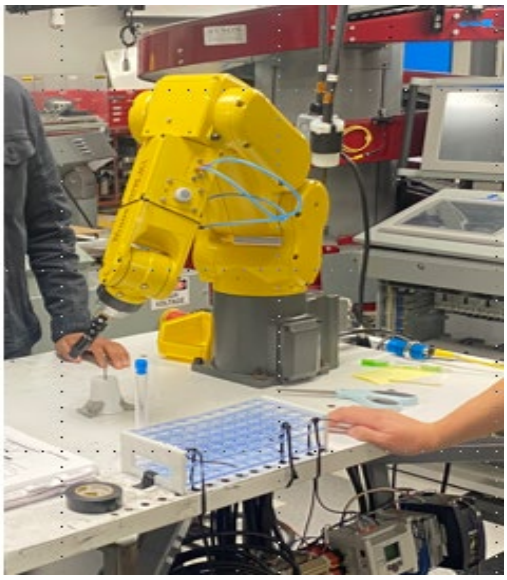
Table1.

Phase 1 Curiosity and Critical Thinking	The objective of this phase is to engage students in critical thinking and curiosity about solving a customer problem and society's needs. Introduce students to EM concepts by looking creatively for real problems or applications that can help society. Search carefully with curiosity, for opportunities that robots can be a part of the solution. Students in this stage conducted a problem identification through group discussion. The students are requested to exchange and examine potential issues related to the project, as well as the social consequences that may arise from utilizing robotics to address the problem. After the successful completion of the first phase of the project, students got the signal to move to the next phase.
Phase-2: Project Proposal	The focus of this phase is to identify new opportunities in the robotic field to solve the problem. Students were also, introduced to the Bio-inspired component of this project such as safety – security, and sustainability. All proposed applications needed to incorporate one biologically inspired aspect to satisfy the project requirement. Students are required to understand the problem carefully and propose a suitable solution. Pitch discussion for every student to the rest of the class proposing the project idea and the potential solution. Feedback from the instructor was given to each student and approval to move to the next step.
Phase 3: Design and Technical Solution	The final phase of the project is the final solution after the feedback and comments were received from the previous stage. Students in this stage focused on the STEAM component specifically art components including. technical design and sketch drawing on the robotics cell including the robot programming approach. Also, provide an informative video showing the project was completed as they proposed. Finally, every team is required to present the final design and functioning program.

.



(a)



(b)

Figure 2. a) Robot Preforming Packaging b) Robot Performing Medical lab applications

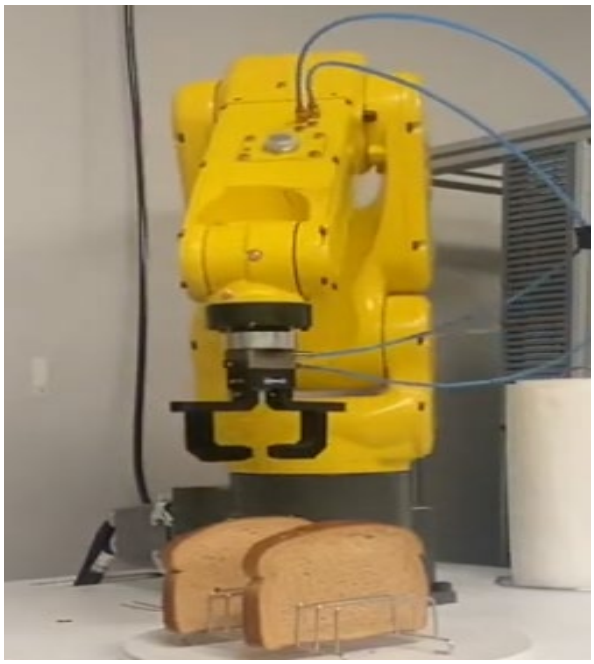


Figure 3. Robot Helping in Food Serving Applications

Also, students submitted a complete lab report including all the steps used in the project implementation and video. Samples of the video links are shown below,
https://www.youtube.com/watch?v=kqpwUJ2-xtk
https://www.youtube.com/watch?v=pF5q8I9uBFk
https://www.youtube.com/watch?v=zflgfY0EDsc

.

3.2 Participants

All participants were enrolled full-time in a sophomore course provided by the engineering technology department to the three programs, electrical and computer engineering technology, mechanical engineering technology, and mechatronics engineering technology. Students enrolled in the minor of industrial robot courses were required to participate in real-world projects. Sixteen students participated in this project, six of the students are seniors, and ten were sophomores. All the students participated in the project but only fourteen of them submitted the completed photovoice metacognitive reflection assignments [16].

3.3 Data Collection Instrument(s)

The data collected from the participating students through the implementation of the new approach through students' reflections promotes. The open-ended survey questions were given to the students to reflect on their perspectives during the project implementations. The open-ended survey questions are provided here [17].

1. *Explain how participating in the newly developed curriculum incorporated the entrepreneurial mindset, and lessons learned relevant to the entrepreneurial mindset. Explain how participating in the newly developed curriculum incorporated STEAM (specifically, the arts), and lessons learned relevant to STEAM (specifically, the arts)*
2. *Explain how participating in the newly developed curriculum incorporated bio-inspired design and lessons learned relevant to bio-inspired design.*
3. *How did this interdisciplinary learning experience affect your ability to engage with the newly developed curriculum?*
4. *What went well? What didn't go so well? What will you do differently next time?*
5. *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)

This study followed a qualitative approach with thematic analysis. According to Braun and Clarke, thematic analysis is a basic qualitative method for discovering patterns in data [18]. It should be done in a step-by-step process. Researchers first familiarized themselves with the data to generate initial codes. After the coding was completed, the theme was generated. The researcher revised the topic and wrote the report as a final step. Researchers debated the advantages and disadvantages between a rigorous conceptualization of the problem without citations and the heavy use of citations to provide evidence to the reader. We decided to fuse the two philosophies and meet in the middle. Citations from the data are intended to allow the reader to make independent judgments as to reliability, accuracy, and fairness [19].

4. Results

The themes are discovered from students' reflections: students improving learning through engagement, and creativity throughout the project process, and the effectiveness of the interdisciplinarity approach. The section below shows samples of the student's comments about each theme.

.

Theme 1: Student learning through engagement

for this project, many strategies include but are not limited to, question-and-answer sessions, discussion, interactive lectures (in which students respond to or ask questions), quick writing assignments, hands-on activities, and experiential learning.

Theme 2: Creativity

Engineers are constantly designing new ideas and concepts to overcome problems. No two problems or issues are the same and for this reason, creativity is highly sought after in the engineering field.

Theme 3: STEAM

STEAM inspires students to use experiential learning that alternates with each of the five areas and builds an inclusive learning environment in which all students can connect and contribute. Students make connections between their current learning and how it can be applied outside of the classroom. All students have different strengths and by encouraging STEAM learning and especially having them work in groups to complete these activities, everyone has a chance to shine.

Theme	Students Quotes
Student learning through engagement	*"To summarize all of them, I found that engineering analysis in specific deals with understanding and predicting physical systems through our environment and Socioeconomics. Ask for the bio-inspired design that has been proven to improve* ***engagemen****t and motivation, I find it very useful. There are many approaches to this matter and the outcomes that I've been inspired by STEAM, and the influences that the entrepreneurial mindset impact has had in the curriculum"* *"To encapsulate them all, I discovered that engineering analysis specifically works with comprehending and foreseeing physical systems by way of socioeconomics and the environment. Request the bio-inspired design, which has been shown to increase motivation and* ***engagement****; I find it to be helpful"* *"The new curriculum focused more on class-wide collaboration. This helped people to work with one another and be exposed to outside thoughts and ideas that they may not have otherwise. As a result, students are* ***more engaged*** *in the topic at hand, rather than just sitting there listening to a lecture. What improves student engagement, as far as engineering students, is opening the class up to a more collaborative environment; as well as showing how arts and bio-design can improve technology"* *"This has motivated me to improve my creativity by being inspired by others, the wonders of nature, and* ***engagement*** *in the student life here at PNW"* "Have *been looking into several approaches to address this e****ngagement*** *in the curriculum. To encapsulate them all, I discovered that engineering analysis*

.

	specifically works with comprehending and foreseeing physical systems by way of socioeconomics and the environment" *"Request the bio-inspired design, which has been shown to increase motivation and **engagement**; I find it to be helpful. There are numerous ways to approach this topic, the results that STEAM has pushed me to achieve, and the curriculum-shaping effects that the entrepreneurial mindset has had"*
Creativity	*"As technology continues to evolve, so too will **man's creativity**. This also means that products could be made from bio-organic origins. For example, body armor used to be knights on horses wearing thick steel plates or other heavy metal composites to protect the user. Now, we are researching the idea of body armor that could be made from spider silk to protect the user from projectiles"* *"The issue was not that they did not have the resources to make such inventions, but the knowledge or even contemplating that such technology could be invented was the greatest wall to progress. As stated before, **creativity** is an engineer's greatest asset in solving a problem. It allows him to take a problem from an unorthodox style that could lead to discoveries. In the realm of robotics, I am sure that we will find more efficient and organic solutions to build the parts that go into the robot"* *"What I learned from this is that technology, especially the field that I am going into, mechatronics, is continuously growing. As man's ability to grow and be **creative** continues, so will the challenges we face in the future. Challenges that will need to be addressed by inventive and unorthodox solutions. What is most important is to promote man's creativity in the field of STEAM. All must work in tandem to professionally design a product or solve a problem. If man's ability to be creative is reduced, then we will fall short of being able to apply STEAM to solve a given problem."* ***"Creativity** plays a big role when drawing, designing, and problem-solving solutions that could not have been thought about in the previous years. Sometimes when life hits, you have to just let your mind lose. Enjoy what nature has to give and then observe how simple nature is. This has motivated me to improve my creativity by being inspired by others, the wonders of nature, and engagement to the student life here at this university"* "*While taking the Programming Industrial Robotics course, I have learned many things over the months. While most of it focuses on the advancement of robotic technology and how to implement safety features, it also delves into another matter, creativity"* *As technology grows, so too will recent problems arise that need to be addressed by engineers. **Creativity** and having a mindset of discovery help the engineer think outside of the box to find new inventive ways to solve a problem.*

.

	A person with an entrepreneurial mindset is someone who thinks about how to go the extra mile to put in the effort to make money. This can lead to innovation and new creative ideas that could help the field that he/she is in" *"While money is not always the driving force behind creativity, it is one of many driving factors that push people to be creative. Having high motivation combined with a* ***creative*** *mindset can be the dynamic duo needed to achieve the goal set out by the manager or leader. While I am not entrepreneurial, I did choose to go into the MCET field so that I could get a job that I enjoy enough to continue working to make good money to help sustain my livelihood.*
STEAM	*"When I first started to read about the Interdisciplinarity approach, I did not know what I was doing. All these steps and ways you can gain an understanding to learn and then apply to your work are a lot to take in. I have broken it down myself by understanding the easiest in which case is* ***STEAM****."* *"****STEAM*** *is intended to combine STEM and arts subjects in a variety of pertinent academic disciplines. These courses build on students' foundation in math and science while teaching innovation, critical thinking, and the application of engineering or technology in imaginative creations or inventive solutions to issues in the real world. By incorporating design and logic into their lessons as well as promoting original thinking,* ***STEAM*** *programs integrate them into* ***STEM*** *curricula."* *Participating in the newly developed curriculums is essential when it comes to understanding the main factors of what is being said. For the inter-disciplinary approach to integrating the* ***STEAM*** *and entrepreneurial mindset, certain factors must be identified"* *"These sculptures exhibit exquisite detail and show off what is possible when a master welder takes his time to incorporate the wonder of nature into his trade. Welding can be art and art can be welding. You simply must employ your hands and let your imagination roam.* ***STEAM*** *as it can transform a simple weld into a masterpiece".* ***STEAM*** *is the use the science, technology, engineering, art, and math and finding STEAM in the engineering world. The first image is the programming robotics which is technology and engineering with the art of the robots."* *"The robotic arm incorporates the* ***STEAM*** *in the engineering side and technology having lessons to program and the movement of the robotic arm, having to control it doing many tasks. The second image is the drawing of an Electrical schematic that helps the* ***STEAM*** *in the engineering side and the art side in it, the drawing is showing how it works by its function in each component."*

.

	*"The connection between the component also needs math to calculate the flow in the schematic. The third image is the movement pocket watch, it shows the math, science, art, and engineering of **STEAM**.* *"The robot is more in the engineering side and the technology as well the form of it is an arm like a human. The STEAM is a curriculum that incorporates the humanities but in engineering to help modern life."* *"Some technology uses the bio-inspired design to be engineering and robotics thus having a well efficient design having the **STEAM** in mind that connects having the art of bio-engineering design in nature to modern technology. Having bio-inspired by modern tech has improved so much many great designs to work using the function of nature. Having to learn bio-inspired design to be in the engineering world would be very efficient as learning biology as well connect to the STEAM curriculum. It will improve the student by learning difficult tasks and soon see them as easy to accomplish. The newly developed curriculum will help students engage in the field and learn the obstacle with the STEAM to help guide them through."*

5. Discussion

In response to the research question (How does the integration of interdisciplinary experiential learning opportunities influence student perceptions of learning and engagement?), this study resulted in 3 themes, student learning through engagement, creativity, and STEAM [20].

The new project approach for the curriculum has created an opportunity for the class to practice working together. Utilizing students' different talents, interests, and experiences to work towards solving new and interesting problems. It is the instructor's hope, that by putting minds, with so many different experiences together in solving a problem, our diversity will allow students to view and go about solving problems in different manners from one another. Where one may find a roadblock, another may see an easy pass-through.

Furthermore, through studies and discussions, students have been exposed to the benefits of divergent thinking and the role that it plays within the industry and in innovation. Divergent thinking is what allows innovators to innovate. It goes hand in hand with interdisciplinary thinking and allows the students to think of a problem or solution in an entirely new light. Through divergent thinking, students can learn to explore problems and solutions in a new light, find new solutions, and create new opportunities. In collaborating with others, the students develop new ideas, are exposed to new ways of thinking, and learn new skills. This will help every student in this course walk away stronger in many aspects than they were before.

The peer discussions and informative feedback from the instructor were significant in facilitating the writing of a complete program in a creative way to solve the problems.

The proposed project focused more on class-wide collaboration. This helped students work with one another and be exposed to outside thoughts and ideas they may not have otherwise. As a result, students are more engaged in the topic at hand, rather than just sitting there listening to a lecture. Moreover, integrating the arts, and bio-inspired design improves student engagement.

.

What improves student engagement, as far as engineering students, is opening the class up to a more collaborative environment; as well as showing how arts and bio-design can improve technology. Students are eager to leverage their experiences in solving the problems at hand while exposing each other to different ways of thinking. this collaborative environment, coupled with experiential learning is what helps students to integrate the desired mindsets into their normal thinking and problem solving, and real-world applications.

6. Conclusion

This study shows the effectiveness of enhancing the programming industrial robot course through the integration of the Entrepreneurial Mindset into the existing course. The study showed the efficiency and effectiveness of this approach through the feedback results obtained from the students. The student's reflections on the open-ended question and the metacognitive reflection assignments borrowed from the text showed the efficacy and creativity of this approach. The integration of the Entrepreneurial Mindset with the STAEM approach helped students to see the value of experiential learning techniques in classroom settings.

Also, this paper showed the lack of opportunities for many engineering students to the real-world problem and application experiences, and internships limitations chances and how this approach can close this gap. This approach was implanted for programming industrial robot courses; however, this approach can be implanted in any engineering and technology classes.

6.1 Summary of Main Takeaway

From a practical perspective, this study provides evidence of learning gains with the curriculum when integrating EM + Bio + STEAM. In addition, this study shows how metacognitive reflections can be used to help students better understand the overarching benefit of completing the project, while at the same time providing the instructor with rich feedback for improving the course. The paper concludes with best practices and lessons learned so other practitioners can easily implement the new curriculum within their classrooms.

6.2 Lesson learned

By implementing an interdisciplinary research project approach that combines EM, STEAM, and Bio, students can acquire practical, hands-on experience that will prepare them better for the workforce. This approach aims to provide real-world experiential learning opportunities to engineering students. This approach helped students to get success in real-world applications. The new approach focused more on class-wide collaboration and experiential learning. This helped students to work with one another and be exposed to outside thoughts and ideas that they may not have otherwise. As a result, students are more engaged in the topic at hand, rather than just sitting there listening to the instructors. The themes are discovered from students' reflections: students improving learning through engagement, activity throughout the project process, and the effectiveness of the interdisciplinarity approach. The section below shows samples of the student's comments about each theme

6.3 Limitations and Future Research

.

The limitation of this study was the metacognitive reflection assignments collected one time after the midterm project. The amount of time allocated to this project was not enough for all students to participate and reflect on their opinions. In the future, the amount of time will be more, and the implantation will include the two projects not only the midterm.

References:

[1] L. Bosman and S. Fernhaber, *Teaching the entrepreneurial mindset to engineers*. Switzerland: Springer International Publishing, 2018.

[2]. H. M. Neck, P. G. Greene, and C. G. Brush, Teaching entrepreneurship: A practice-based approach: Edward Elgar Publishing, 2014.

[3]. S. Segar, "The benefits of experiential learning," *Experiential Learning Depot*, 31-Aug-2021. [Online]. Available: https://www.experientiallearningdepot.com/experiential-learning-blog/the-benefits-of-experiential-learning. [Accessed: 12-Dec-2022].

[4] Sheppard, Sheri D., Kelly Macatangay, Anne Colby, William M. Sullivan, Educating Engineer Book Highlights; The Carnegie Foundation for the Advancement of Teaching; Winter 2008 http://www.carnegiefoundation.org/dynamic/publications/elibrary_pdf_7 69.pdf

[5] "Fourteen Grand Challenges for Engineering in the 21st Century," Grand Challenges – 14 grand challenges for engineering. [Online]. Available: http://www.engineeringchallenges.org/challenges.aspx. [Accessed: 13-Nov-2022].

[6]. HESA [Higher Education Statistics Agency], 2011 HESA [Higher Education Statistics Agency] Joint Academic Coding System (JACS) Version 3.0 https://www.hesa.ac.uk/jacs3 (2011)

[7] Transforming Engineering with Entrepreneurial Mindset, *https://engineeringunleashed.com/*. [Online]. Available: http://www.engineeringchallenges.org/challenges.aspx. [Accessed: 13-Nov-2022].

[8] Mann, C. Riborg., Joint committee on engineering education of the national engineering societies. (1918). A study of engineering education: prepared for the Joint Committee on Engineering Education of the National Engineering Societies. Boston: Merrymount Press.

[9] Kong Y. The Role of Experiential Learning on Students' Motivation and Classroom Engagement. Front Psychol. 2021 Oct 22; DOI: 10.3389/fpsyg.2021.771272. PMID: 34744950; PMCID: PMC8569223.

[10]. Hora, M. (2020) Obstacles that stop many students from taking an internship, WCER. Available at: https://wcer.wisc.edu/news/detail/5-obstacles-that-stop-many-students-from-taking-an-internship (Accessed: November 13, 2022).

.

[11]. Potter, P. W. 2009. The Experience of Experiential Exercises in Management Classes: A Professor's View. Research In Higher Education Journal 3: 10 pages.

[12]. A. J. Conger, B. Gilchrist, J. P. Holloway, A. Huang-Saad, V. Sick and T. H. Zurbuchen, "Experiential Learning Programs for the Future of Engineering Education," *2010 IEEE Transforming Engineering Education: Creating Interdisciplinary Skills for Complex Global Environments*, 2010, pp. 1-14, DOI: 10.1109/TEE.2010.5508822.

[13]. L. Bosman and S. Fernhaber, Teaching the entrepreneurial mindset to engineers. Switzerland: Springer International Publishing, 2018.

[14] . R. N. Coger and H. V De Silva, "An integrated approach to teaching biotechnology and bioengineering to an interdisciplinary audience," Int. J. Eng. Educ., vol. 15, no. 4, pp. 256–264, 1999.

[15]. M. A. Kanny, L. J. Sax, and T. A. Riggers-Piehl, "Investigating forty years of STEM research: How explanations for the gender gap have evolved," J. Women Minor. Sci. Eng., vol. 20, no. 2, 2014.

[16]. Bosman, L., Duval-Council, N., and Jarr, K., "Mentoring Engineering Educators with an Entrepreneurial Mindset – Focused SOTL Professional Development Experience."

[17] Bosman, Lisa, and Katey Shirey. "Using Bio-Inspired Design and STEAM to Teach the Entrepreneurial Mindset to Engineers." 2022 ASEE Annual Conference & Exposition. 2022.

[18] Useche, A.C., Galvis, Á.H., Díaz-Barriga Arceo, F. et al. Reflexive pedagogy at the heart of educational digital transformation in Latin American higher education institutions. Int J Educ Technol High Educ 19, 62 (2022). https://doi.org/10.1186/s41239-022-00365-3

[19] Corden, A., & Sainsbury, R. (2006). Using verbatim quotations in reporting qualitative social research: Researchers' views. Social Policy Research Unit, University of York. https://www.york.ac.uk/inst/spru/pubs/pdf/verbquotresearch.pdf.

[20] L. Bosman and S. Fernhaber, Teaching the entrepreneurial mindset across the university: An integrative approach. Springer, 2021