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Promoting Entrepreneurial Mindset in Engineering Students Using IoT-Focused Project-Based Learning

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1. Introduction

1.1 Problem Identification

In a recent report by the Society of Human Resource Management, over 50% of industry executives reported that recent college graduates lack problem-solving, critical thinking, innovation, and creativity. The report also identified communication and teamwork skills as other missing attributes in recent engineering graduates [1]. In its 2019 Job Outlook survey, the National Association of Colleges and Employers [2] ranked problem-solving skills as the second most important skill required by employers, with written communication skills being number one. The top ten required attributes included "ability to work in a team, initiative, and analytical skills." For the first time, entrepreneurial skills were reported as a desired attribute by 16.9% of the participants.

The problem is that engineering students' exposure to practicing these skills is often limited to senior capstone courses. Throughout their technical training, engineering students are introduced to problem-solving techniques using closed-ended, well-defined problems with one correct answer. This pedagogical approach encourages the use of convergent thinking: the use of logic to arrive at one correct solution [3]. Several studies have shown that the thinking approach used to analyze traditional problems in the engineering classroom does not provide students with the required skills to solve real-world problems [4]. In contrast, authentic, open-ended projects require divergent thinking which includes independent thinking, creativity, and innovation, all of which are rarely encouraged or practiced in classes leading to capstone design courses. Although creative problem-solving in engineering requires both convergent and divergent forms of thinking [3], the current curriculum provides students predominantly with the former over the latter.

Likewise, traditional approaches to engineering education rarely provide students the opportunity to practice communication and team working skills. ABET requires soft (professional) skills such as "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" [criteria 3 (5)] and "an ability to communicate effectively with a range of audiences" [criteria 3 (3)], to be assessed once during the curriculum [5]. However, engineering graduates frequently face the challenge of acquiring or perfecting these skills in their first year of employment. Consequently, to prepare students to compete in a highly competitive job market, engineering programs must incorporate critical thinking and soft-skills training early in the engineering curriculum and in more than one exit class.

1.2 Limitations of Current Approaches

All engineering programs require students enrolled in capstone classes to apply their knowledge and technical skills to produce a solution to a real-world problem. While these courses provide students with an opportunity to learn and practice workplace skills, the approach only ensures that some students get practice with every aspect of the design process. In most collaborative projects, tasks are delegated to individuals in the groups, which allows them to only practice some aspects of the design process. Additionally, the capstone course approach does not expose students to other engineering disciplines, nor do they focus on promoting creativity, innovation, or other professional skills. Further, most engineering classes often use closed-ended, well-defined problem-solving techniques to introduce technical topics. These approaches can be easily utilized to assess ABET learning outcomes; however, they have little effect on developing critical thinking and problem-solving skills [6]. Professional organizations, such as the Society of Women Engineers (SWE) and the Institute of Electrical and Electronics Engineers (IEEE), do offer students the opportunity to participate in open-ended design projects or activities. However, these opportunities are limited only to students who take advantage of these opportunities. Likewise, while communication and teamwork skills can be encouraged in team-based lab assignments and group projects, it can be a struggle to ensure that all students participate equally in the learning process or get an adequate chance to practice interpersonal and leadership skills.

1.3 Study Overview

In this paper, we present findings from implementing an Internet of Things (IoT) project activity in a computer engineering class to promote interdisciplinary research and an entrepreneurial mindset (EM). The project-based learning (PBL) activity provided students with a chance to propose, plan, design, and implement solutions to real-world problems while enhancing their communication and teamwork skills. Using multiple assignments, students were directed to propose an Internet of Things (IoT) based system with real-world connections and gather feedback from a real audience to support their design proposals. This supplied a goal and purpose for the activity and was a leading factor in exploration. To support promoting the EM in the activity, students focused on providing a solution to a real-world problem and proposing a market-driven solution based on research and product analysis. Proposals were also required to integrate Bio-inspired components in their designs and use media artworks to reflect purpose and audience in the final product.

Over six weeks, students were introduced to several system design components. A preliminary analysis of results indicated that the hands-on experience facilitated higher-order reasoning and allowed the students to think systematically about the feasibility and functionality of their design solutions. The research focused on studying the effectiveness of the proposed approach in developing EM, problem-solving, communication, and teamwork skills in engineering students. The researchers employed qualitative thematic analysis of student feedback and reflections on their project learning experience using photovoice prompts to collect the data.

2. Literature Review

In their 2020 annual symposium [7], The National Academies of Sciences, Engineering, and Medicine invited speakers representing universities from around the world to share information about goals, priorities, and dreams for improving undergraduate STEM education. “What changes are needed to undergraduate STEM education in light of the increasing convergence across STEM disciplines?" and "What are critical convergent topics and approaches we urgently need to incorporate into undergraduate STEM education?" were among the topics addressed during the week's event. Based on their experiences in higher education, the participants acknowledged that education today is more focused on content and skills than creativity and promoting critical thinking. In their conclusions, they recommended several approaches to improve undergraduate STEM learning and create successful student experiences. Project-based learning, real-world problem solving, creative assessments that measure critical thinking, experiential activities that cross disciplines, and teamwork were identified as key approaches that educators should focus on to prepare students today for the future.

On the other hand, Industry representatives shared their experiences and recommendations on educating engineers for the 21st century during the National Academy of Engineering annual meeting in [8]. While acknowledging that engineering schools already produce technically competent graduates, they need engineers who are: creative, can work in teams, and can communicate and share their thoughts and ideas. They emphasized that engineering schools should involve students in projects from day one and not rely on capstone design to practice problem-solving and learn about partnerships, relationships, and exchanging ideas. To help meet this challenge, Jarrar and Anis suggested that integrating entrepreneurial education into the engineering curriculum had a significant impact on improving creativity, critical thinking, and problem-solving skills [9]. Shane and Venkataraman defined entrepreneurship as "the discovery, evaluation, and exploitation of opportunity" [10]. Academic research on teaching the EM suggests that developing an entrepreneurial mindset in engineering students is a process that requires practice and repetition. Consequently, EM should be incorporated in courses throughout their educational career and not limited to one or two courses.

Once implemented, entrepreneurial education provides students with an opportunity to use their technical knowledge to meet market demands and create solutions to real-world problems. It allows the students to become problem-finders and problem-solvers [11]. The entrepreneurial process encourages students to identify opportunities or needs based on their experiences, which promotes a higher level of engagement and allows learning expansion. It also trains engineers to become effective communicators and team players with the ability to solve multidisciplinary engineering problems [12].

Meanwhile, as noted in [13], the project-based learning approach grants students the freedom to become active learners and produces a positive impact on their performance. Project-based learning is a teaching methodology that allows students to acquire the knowledge and expertise of the learned concepts using project development. Many researchers have identified PBL as a successful tool in improving the quality of student knowledge, developing knowledge, and creating a positive attitude toward learning [13-16].

In this research, we introduce a framework in a computer engineering class that combines PBL and EM to promote critical thinking, creativity, interdisciplinary research, teamwork, and enhance communication skills. The framework utilizes PBL to provide students with hands-on entrepreneurial experience in the context of an Internet of Things design project. In [13], Arias et al. proposed integrating Entrepreneurship education in computer engineering master's degree programs using a PBL approach. However, the method was applied to the master's degree program and was focused on a common project.

Interdisciplinary research was encouraged by integrating the Bio-inspired design (BID) aspect into the projects. Arizona State University's Biodesign Institution defines BID as "Harnessing the natural design rules of biology and translating solutions from one area to another to address complex challenges." It identified sustainability, security, and biomedicine as the three areas of focus in the 21st century. Through their projects in the course, students researched targeted animal security, defined as "the process of protecting farm animals and house pets from natural disasters or predators." As a result, the course included a relevant, place-based aspect to the assignment since agriculture is an integral part of Northern California's culture and economy.

Finally, the project's requirements considered integrating Arts into the design to promote creativity and originality. Studies have proven that integrating Art in STEM education (STEAM) provides an opportunity to bolster creativity and increase student achievement [17]. Art integration can be achieved using any form of Visual Art, such as drawing, painting, sculpture, crafts, or photography.

By incorporating PBL, BID, ART, and EM in an undergraduate computer engineering course, we attempt to focus on filling the gap between skills and forms of thinking required by the industries and those developed by traditional engineering classes.

3. Methods

3.1 Study Design

This study presents a six-week project assignment used to spark and develop the entrepreneurial mindset in engineering students and encourage creativity and originality. EM was introduced to students as "The inclination to discover, evaluate and exploit opportunities" [3]. The Entrepreneurial Mindset model adopted in this study focuses on product development and continuous improvement.

Students started by searching and evaluating available IoT systems in the market targeting house or farm animals' security. This process allowed students to identify the need and marketability of their proposed designs and establish a better understanding of system requirements. All proposed designs needed to incorporate one biologically inspired aspect and satisfy all IoT systems requirements, including networking, user-friendly interface, sensing, and actuating.

The project was assigned to students using four milestones, each associated with a set of deliverables for evaluation and assessment. A summary of the four milestones is presented in Table 1 below.

Table 1: Assignment Milestones and Objectives

Milestone	**Objectives and Tasks**
Milestone 1: Research and analysis.	Introduce students to Bio-based IoT systems in the market. Students formed groups to search, select, and analyze one IoT system targeting animals' security or safety.
Milestone 2: Project Proposal	Promote and instill an entrepreneurial mindset through the planning and development of the system design. All groups were directed to select a design that could fit in one of the bio-inspired fields: sustainability, biomedicine, or security.
Milestone 3: Design Prototype	Identify all hardware and software components needed to create a complete design prototype. Groups were required to submit a structural presentation of their designs.
Milestone 4: Complete Design and Presentation	Build and present a complete working system. Each group was given fifteen minutes to present their design. All group members were required to fill out an assessment report to reflect on their participation experience.

3.2 Participants

The class in this study, "Introduction to Internet of Things (IoT) Systems Design," is a junior-level Electrical and Computer Engineering upper-division elective. Students enrolled in the class were required to participate in the research as a project assignment. While all students submitted the data collection assignment for class credit, only eight participated in the study. Seven of the participating students were seniors and one junior. All students were majoring in Electrical or Computer Engineering except one in the Advanced Manufacturing and Applied Robotics program. Students in the class were given the option of selecting their project team members. Two students worked individually, and six worked in groups of two. Participants' gender and race were not collected or used for the purpose of this study. The university IRB approved the research, and all participants were informed that the project would be used for research.

3.3 Data Collection Instrument(s)

All students in the class were required to complete a photovoice reflection assignment as part of their four milestone submissions [17]. Photovoice is a qualitative learning assessment tool developed in the mid-1990s as a participatory methodology [18]. The tool has been modified and adapted in pedagogical research to observe students learning and study their engagement in learning activities.

Photovoice was used in the project to collect and analyze data using a combination of photos with captions and reflections. Students were directed to complete a photovoice assignment and answer several prompts using three pictures and a written narrative for each prompt. Three prompts were designed to directly evaluate the project's learning objectives, developing an EM, incorporating a Bio-inspired design, and STEAM. The remaining three were used to assess and evaluate the impact of the proposed teaching paradigm. The following prompts were used in the assignment:

1. Explain how participating in the project incorporated the entrepreneurial mindset.
2. Explain how participating in the project incorporated STEAM, specifically arts.
3. Explain how participating in the project incorporated bio-inspired design.
4. How did this interdisciplinary learning experience affect your ability to engage with the curriculum?
5. What went well? What didn't go well? What will you do differently next time?
6. What skills did you learn? Please consider both professional skills and context-specific skills. Why are these skills important for engineers in the real world?

3.4 Data Analysis Procedure(s)

The researchers used ATLAS.ti qualitative analysis software and employed grounded theory [19] and constant comparative analysis [20] to code the qualitative data and arrive at themes. The researchers collaboratively completed the first round of open coding using a small subset of the data to agree upon an initial set of codes. To reach an agreement on the codes, all researchers read a student response, discussed its meaning as well as possible labels for the code, and then agreed upon an initial code. As initial coding continued, the labels for each code were refined based on the analysis of additional sections of text. Using the initial codes, the authors engaged in constant comparative analysis with all subsequent student responses mitigating any need to further obtain intercoder reliability. Memos of individual codes were then used to group codes into themes. It should be noted that quantitative analysis and the final project's evaluation were not analyzed as part of this research.

4. Results

Students' responses to the photovoice prompts were aggregated and used for the qualitative analysis. A sample of the student's responses is shown in Figure 1 below.

*Photovoice Reflection Prompt A (**Entrepreneurial Mindset**): The entrepreneurial mindset is defined as "the inclination to discover, evaluate, and exploit opportunities." Explain how participating in project 1 incorporated the entrepreneurial mindset, and lessons learned relevant to the entrepreneurial mindset.*		
		
The process is about finding problems and making solutions	There is a lot of risk and to understand whether there will be loss it can be a numbers game	Sometimes it can be a series of failures until you can be successful
I feel like participating in project 1 helped develop the entrepreneurial mindset by making us develop a solution to a problem that we found. I feel like that's what being an entrepreneur is all about, finding a problem in the world and then developing and selling the solution. It helped that the project was presented to us very broadly with just a general topic/field to try and develop our project in. In this case it had to be something that had to do with livestock, that was the general field that we were given to develop ideas for what we wanted to do for our project. So, we pretty much went into it thinking about all the problems people can have with livestock and settled on the problem some smaller local farmers have with their livestock being hunted and killed by local wild predators. And part of our project process was finding out whether our solution to this problem would be viable if we were to try and put it on the market. In that process we found that people in the farming business would often not really know whether the product would be successful unless it could be demonstrated to work, and that kind of gave us a view as to the risk that we could be taking if we were to try and follow through with making this a true commercial product. Overall, this process helped with the project development process for not just the entrepreneurial mindset but the engineering mindset we are trying to develop as well because I feel that they are closely related.		

Figure 1: Photovoice Reflection Sample

Open and initial coding of the student-written data resulted in the 17 codes shown in Figure 2 below. The numbers beside each code represent the number of student quotes in that code. The researchers also wrote memos for each code to summarize the meaning of each quotation.

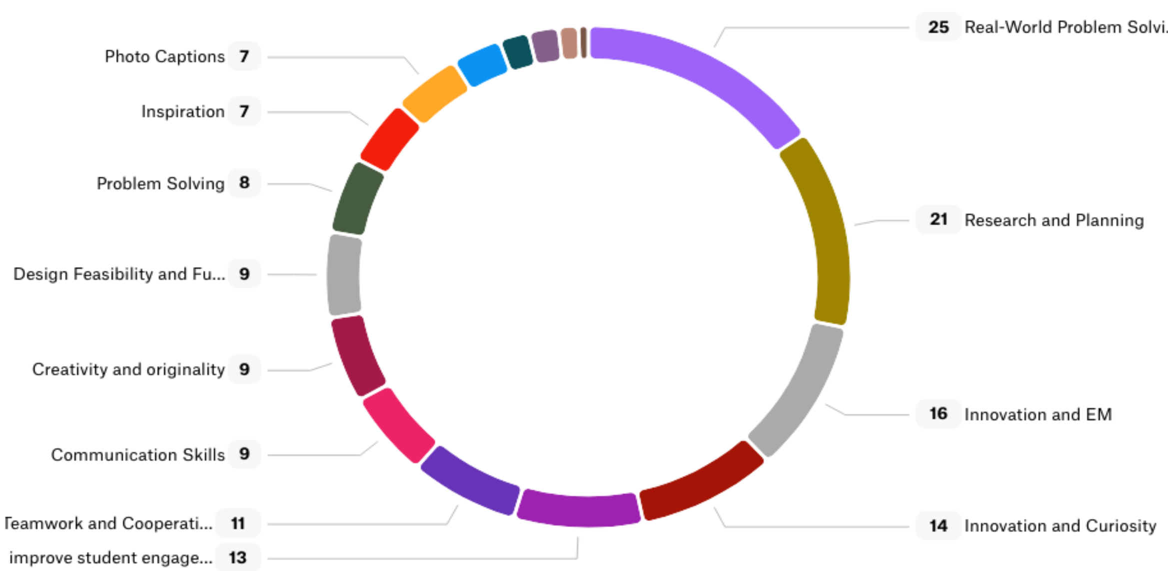

Figure 2: Codes and students' results

During the focused coding phase of the grounded theoretical analysis, the 17 codes were collapsed into six themes by reading the quotes and their associated memos for each code and comparing and contrasting the meanings between the various codes. The six themes' definitions and their representative student quotations are presented in Table 2 and Table 3 below. Quotes that appear in two themes were double-coded.

Table 2: Sample of Students' reflections

Theme	Description of Theme
Encouraging Creativity and Innovation.	Proposing a new useful design and successfully implementing it
Interdisciplinary Thinking and Transfer of Knowledge to New Contexts	Making connections between different fields.
Real-World Problem Solving	Focusing on proposing a design that provides a novel solution to a real-world problem based on the research question.
Leadership, Time Management, and Communication Skills	Establishing a plan to meet deadlines through delegating tasks and managing time effectively.
Making Contributions to Society by Creating More Sustainable and Equitable Systems	Considering the effect of the final product on the environment.
Persistence and Resilience Facilitated by Engagement and Enjoyment	Insisting on completing the task, despite failing attempts, prompted by dedication and enjoyment.

Table 3: Themes and students' quotes

Theme	Students Quotes
Encouraging Creativity and Innovation.	I think trying to add your own flair to a project is very important as a student or even as a person with interest in a field. It takes away from the monotony and cookie-cutter process that is being done and allows the student to have more fun with the project. This, in turns fosters more interest and excitement towards the field and allows the project to be much more than just homework. I have been interested in how technology can help make agriculture more efficient and environmentally friendly. I'm convinced indoor farming is the future, and automated robotics (figure 2) will make it much more viable. Learning more about designing IoT helps me imagine how I would design systems for indoor farming. I have been working on personal projects the use computer vision for some time, and once I read more about there are automated rovers that study each plant in a crop field for signs of illness I became very intrigued. All I could think about in my day-to-day life was, "what system can I design that would make this task better? Technologies that, although perhaps not revolutionary, have great potential to solve shortcomings in humanity's current capacity. The more I read about what others are

	doing using IoT systems, I became more inspired and energized to contribute to society using the knowledge I have acquired over my life and my time in university. The chance to research, evaluate, create, and pursue my own project that I thought of that still falls within the class scope causes much more engagement personally because I had a hand in the entire process. The project also improved on the use of knowledge from different fields in the creation of a solution. The main action in the activity is an invention, which is a challenging action in learning experiences. Invention compels someone to exploit as many knowledge areas and skills as possible in the quest for solution creation and promotion. The project compels one to get into the shoes of a consumer and picture a problem clearly, then invent a solution that is relevant and reliable. Innovation and creativity were also other skill emphasized during the project, In this project, I felt like this was the first time I had a complete free range of something that I wanted to build myself. Although creating the ideas were rough, I felt like it was a great step in figuring out how to research and use other peoples examples to create a unique prototype of our own. Adding these extra bells and whistles made me more excited to finish the project. It flexes a part of my creative brain that doesn't quite get worked in the projects that I'm used to working on in school and I appreciate that a lot.
Interdisciplinary Thinking and Transfer of Knowledge to New Contexts	Making the connection between hobby and engineering allows me to think about how electrical engineering can contribute to agriculture as well as small gardens. This is making me connect my passion for an engineer with my other interests. Doing so can help me become inspired with new ideas, potentially something that has never been thought of Being asked to do this assignment forced me to reflect more on how all this ties together and how I can use my knowledge from this course and other courses, to create real -world applications. I had always viewed engineer and woodworking as two separate parts of my life, but I realize now that I can use my engineering education to make contributions related to woodworking; new technologies that can open doors to new design and manufacturing techniques. I would use hand tools exclusively and create wonderful artistic and functional pieces. While working on project 1, I started to think about how I might be able to combine the two. I began looking into making my CNC machine, lathe, or laser engraver. Although all of this can be purchased, there is a certain kind of pleasure that only arises from creating things yourself. I think, using the knowledge from my engineering education as well as research, I can design and build several electronic systems that can be used in my hobby of woodworking, allowing me to complete work quicker and with greater consistency Engineering has been my true passion for most of my life, but arts have played a huge role in exercising my creativity as well as my passion to learn. A few months ago, I reignited my interest in drawing, and last week I drew this (figure 1). The fact

	that I was able to incorporate the sketch into the project brought me joy as well as amusement from the "kicks" resulting from the project. STEAM helped me engage with the curriculum as it allowed us to choose a project we wanted to do. Art has always been something I enjoy doing, so being able to implement it into my engineering work has given me an extra push to try my best to create something good I am on the constant hunt for interesting ways I can make an impact on the world using my university education. I now see that my education can provide potential solutions to global issues I had already been passionate about, such as reducing crop death resulting in famine as well as reducing the environmental impact that our agriculture industry has.
Real-World Problem Solving	One should research before committing to a project, and just because the engineer would like the end product does not necessarily mean that the average person will" The challenging aspect of the activity got me into researching and using knowledge from fields that I am already had interest in . The engagement created by the actions of project 1 open-ended up my mind, especially in terms of the ability to source knowledge to create relevant and reliable solutions. A large reason why I decide to pursue the engineering route was that the thought of creating these cool contraptions or systems I see in everyday life would be so exciting and the way this project was structured delved much more into that original motivation thanks to instilling the entrepreneurial mindset and STEAM The need to interview potential clients made this project feel like the development process for an actual product. The need to evaluate the project and create a design that can be used in the real-world made me realize the potential for selling the product. There is potential for growth and for new products to be made by evolving this project idea. Other applicable and critical skills learned are critical thinking and problem-solving. The project activity contained challenges, which needed analysis, understanding, and specific solutions. The real-world setup is always presenting challenges and predicaments that are not planned; this was experienced in the project as well. Considering the unpredictability of implementation, the project improved my problem-solving and critical thinking skills. I feel like that's what being an entrepreneur is all about, finding a problem in the world and then developing and selling the solution. It helped that the project was presented to us very broadly with just a general topic/field to try and develop our project in.
Leadership, Time Management, and Communication Skills	I learned the importance of communicating and scheduling. It is not enough to be open to communication, it is also necessary to take a step forward and initiate communication if you want work to be done. As early on as the first milestone, I started learning how to set and divide the workload amongst the group mates. Laying out what needs to be done and analyzing the tasks to appropriately and evenly divide the workload allows for so much more efficiency in these group meetings

	The biggest skill I learned almost immediately was collaboration and communication skills. Being able to decide who has what role and being able to effectively show how far we are with our parts made me feel like this project was going smoothly throughout this whole semester The other skill I learned while working on this project is the importance of communication. My partner and I needed to be able to have conversations about how we thought the project should go and any disagreements that came along the way in a calm and well-thought-out manner. Discussing each person's wants and hearing each other out, enforced this skill. I felt like being in charge of organizing and completing the parts that I could complete were the most efficient way we completed project 1, and for the future, I hope that we continue to use this process as it helps me understand major concepts in the class as well In the future, I plan to manage my time better through scheduling. I will focus first on the simpler parts of the project before working on the more complex parts….. I also plan to keep my teammates up to date about my progress. I think the reason we had such great communication and collaboration together was that each of us was able to step up and state our thoughts freely. Each one of us had some skills that were better than others, of course, but each of us also felt that we were making an impact on the project instead of sitting out and letting their teammates do the work for them this class is a complicated class for me, but being able to step up and ask my group mates questions on whether I did my role correctly as well as helping putting input on where we should work helped me a lot improve throughout the semester.
Making Contributions to Society by Creating More Sustainable and Equitable Systems	Implementing an affordable and scalable system of plant and animal data analysis would greatly help those in less developed nations produce healthier yields. …make agriculture more efficient and environmentally friendly Through the project activity, one learned social skills such as empathy and understanding. Empathy, understanding, and regard are social virtues that an entrepreneur needs for him/her to understand a problem and how it will be solved I became more inspired and energized to contribute to society using the knowledge I have acquired over my life and my time in university independent research is inspiring me with new ideas of IoT systems that can help remedy difficulties and better society. I am on the constant hunt for interesting ways I can make an impact on the world using my university education. I now see that my education can provide potential solutions to global issues I had already been passionate about, such as reducing crop death resulting in famine as well as reducing the environmental impact that our agriculture industry has.

Persistence and Resilience Facilitated by Engagement and Enjoyment	I even saw it when I was trying to figure out I2C. Though I fiercely struggled with it, I saw that I was much more willing and content with failing or hitting walls when trying to figure it out compared to in the past when I would give up much quicker, and the frustration sets in. I felt like I wanted to make better improvements on the design instead of focusing on making the design for a grade. trying to incorporate some sort of art or flair into the project made it more enjoyable. This seemingly small thing brought me a lot of joy because I thought it was just funny. Adding these extra bells and whistles made me more excited to finish the project. It flexes a part of my creative brain that doesn't quite get worked in the projects that I'm used to working on in school and I appreciate that a lot. I think trying to add your own flair to a project is very important as a student or even as a person with interest in a field. It takes away from the monotony and cookie-cutter process that is being done and allows the student to have more fun with the project. The chance to research, evaluate, create, and pursue my project that I thought of that still fell within the class scope caused much more engagement personally because I had a hand in the entire process. l learned more about this new engineering field and how one would apply it to real-world solutions. I learned how to perform research on some disciplines and think critically about how technology might be able to contribute to that discipline. Reading up on electrical engineering contributions to agriculture has spiked my interest and motivation. The integration of the entrepreneurial mindset had the most effect on my learning experience because it is something I am not used to as a student. Besides my senior project class, all the projects I had done were " cookie cutter " projects where we followed a script telling us what to do. Getting exposed to more open-ended projects gives us a real-world scenario and helps us really engage with the material. The project also gave me satisfaction, as I was taking part in something challenging and creating a solution to an actual problem in the market. The challenging aspect of the activity got me into researching and using knowledge from fields in that I already had an interest. The engagement created by the actions of project 1 opened up my mind, especially in terms of the ability to source knowledge to create relevant and reliable solutions.

5. Discussion

5.1 Theoretical Interpretation

The thematic analysis of student responses to the photovoice prompts demonstrated that the project engaged students in the skills and attributes called for by professionals in both industry and engineering education. For instance, the theme of Real-World Problem Solving aligns directly with the second most important skill identified by employers [2]. In this theme, the students commented that the open-ended nature and real-world connections of the project not only increased their interest and engagement levels in solving the problem but it also allowed them to see the project's connections to developing an entrepreneurial mindset by connecting with consumers and evaluating the project based on its value to customers. Further, in the theme of Encouraging Creativity and Innovation, the open-ended nature of the project increased student agency which in turn promoted both innovation and creativity. Students stated that adding "bells and whistles" and "their own flair to the project", and the fact that they were encouraged to add artistic features to their designs inspired them to think more creatively than in previous class projects. The project also promoted interdisciplinary thinking, helping students make connections to hobbies and other aspects of their lives such as IoT system applications to gardening, agriculture, and woodworking. The STEAM aspect of the project helped one student see the connections between art and engineering design.

Persistence and resilience are central to success in engineering because failure is a central aspect of the engineering design process. Consequently, effective engineers need to be both persistent and resilient in the face of failure. Overall, the students stated that the project was so engaging and enjoyable that it motivated them to complete the project much more than the "cookie-cutter" assignments in their other courses. Further, one student stated that the project was very challenging and that they struggled to complete it, but despite "failing or hitting walls when trying to figure it out" that they persisted "compared to the past when I would give up much quicker, and the frustration sets in".

While most of the themes above focused on promoting more divergent forms of thinking, convergent forms of thinking, also important for engineering design, were found in the Leadership theme. Students wrote about collaboration, task delegation, efficiency, and time management. Importantly, some students stated that the project promoted their leadership and project management abilities by providing opportunities to facilitate efficient meetings by analyzing and delegating both roles and tasks in a way that accentuated individual team member strengths. Also central to this theme was developing the ability to communicate effectively in team meetings which involved both sharing information, but more importantly, listening to team members' ideas and input, all for the goal of completing a high-quality project in a timely fashion.

While not explicitly part of the project, several students mentioned that the project inspired them to create IoT systems that would promote sustainability and equity by stating that they wanted to "help remedy difficulties and better society," to "help those in less developed nations produce healthier yields," "make agriculture more efficient and environmentally friendly."

5.2 Implications for Practitioners

The findings suggest collaborative, open-ended inquiry projects with real-world connections should be implemented in courses throughout engineering programs, not just during senior capstone projects. Such vertical alignment of curricula provides students with a progression of experiences with multiple opportunities to practice and develop a variety of skills required for engineers during their first years of employment and beyond. Providing multiple opportunities to practice these skills is required due to the complex nature of the divergent and convergent forms of thinking required.

Further, the kinds of thinking required for first-year engineers are essentially all levels of Bloom's Taxonomy of Cognition [21]. Students need to recall and understand science and engineering concepts, apply them in their approaches to solving the problem, analyze results, evaluate the effectiveness of solutions, and create a new product. Such higher forms of thinking take repeated practice to fully develop. For example, to be successful in the project for this course, students needed to recall and understand all main components of the IoT architecture, apply their knowledge to design a complete IoT system, analyze and evaluate the system to ensure it satisfies all requirements, build the design, and test it to evaluate its effectiveness.

Finally, when defining EM for students, professors should emphasize those who think about innovation and continuous improvement and not limit it to startups, which can help them view continuous improvement within the discipline as a form of innovation.

6. Conclusion

6.1 Response to Research Objective

The problem is that engineering students' exposure to practicing soft skills, such as problem-solving, critical thinking, innovation, and creativity, is often limited to capstone courses. The research objective of this study is to extend and contribute to the literature by showing how entrepreneurially minded interdisciplinary learning experiences can be integrated into a technical-heavy engineering course to optimize student learning.

6.2 Summary of Main Takeaway

The main takeaways from this study can be summarized as follows:

1. This study provides an example computer engineering course curriculum that responds to the industry demands on engineering graduates to have a better application of professional and soft skills.
2. This study supports ABET learning outcomes. The proposed model can be used to assess ABET criteria 3 learning outcomes 3 and 5.
3. This study investigated a research project implemented in a non-design course, which traditionally focused on technical content and offered limited exposure to interdisciplinary learning opportunities.
4. This study demonstrates that applying entrepreneurially minded learning not only helped students to discover, evaluate, and exploit opportunities but also resulted in the six themes:
    a. Encouraging Creativity and Innovation
    b. Interdisciplinary Thinking and Transfer of Knowledge to New Contexts

c. Real-World Problem Solving

d. Leadership, Time Management, and Communication Skills

e. Making Contributions to Society by Creating More Sustainable and Equitable Systems

f. Persistence and Resilience Facilitated by Engagement and Enjoyment

6.3 Limitations and Future Research

This study was conducted in a junior-level elective class with nine students. The limited number of students in the class allowed for close interaction and observation of all students. It also facilitated the application of the learned concepts in the activity sections with one-on-one supervision. With a larger number of students in the class, a modification is needed to accommodate all students. The assignment can be expanded into 10-15 weeks instead of the six weeks in this study. Also, students can be directed to explore solutions in other fields that are not tied to bio-inspired designs.

One limitation of the study could be considered the small number of student participants. However, the current study was conducted from an interpretive perspective employing qualitative research. Instead of generalizability, qualitative research is grounded in the notion of transferability [22], in which researchers provide a description of the context, along with transparent findings, placing the burden of generalizability with the reader [23]. The current research aimed not to generalize to other settings but to provide a deep description of the student experience in this course.

In future implementations, the method can be applied to other electrical and computer engineering courses and use quantitative and qualitative data collection approaches. It can also be used to assess ABET's [criteria 3 (5) & (2)] in several core courses in the engineering curriculum.

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