Paper ID #45445

Impact of an Interdisciplinary Engineering Design Project on First Year Students

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Abstract

Increasing student interest in science, technology, engineering and mathematics (STEM) continues to be of significant importance in order to satisfy the increasing demand for professionals in these fields. The First Year Scholars program at Kennesaw State University (KSU) aims to introduce first-year students to the undergraduate research experience. Students are encouraged to apply for projects they find interesting, regardless of whether the projects are in their majors. This program helps students gain early research experience, which sets them on a path for future success. In this study, an interdisciplinary engineering project was developed that required students from both the mechanical and electrical disciplines to work collaboratively on designing a Smart Helmet for cyclists. The students had minimal expertise in engineering design but were presented with a problem that required them to learn and acquire several new skills that they did not possess. The impact of the project was examined based on their performance and through the use of a survey which they completed at the end of the project. The results were very favorable and indicated that the interdisciplinary nature of the project had motivated them to pursue a career in the engineering field. They also believed the skills they acquired through the project, sparked further interest in pursuing more advanced courses in the engineering curriculum.

Introduction

Providing undergraduate students with relevant skills in science, technology, engineering and mathematics (STEM) continues to be a challenge for educators [1], [2], [3]. Various projectbased learning approaches have been implemented to achieve this goal such as engineering design-based instruction (EDBI) [4] and the STEM Engineering Design Learning Cycle (STEMEDELCY) model [5]. The use of interdisciplinary engineering design projects have been successfully implemented in Capstone projects. At that point, students have already acquired significant knowledge from their core discipline [6], [7], [8], [9]. However, research indicates that exposing students to engineering design activities in the earlier years of their undergraduate study has also provides several benefits [10], [11], [12]. This study examines the impact of implementing an interdisciplinary engineering project to first year students.

The project was part of the First Year Scholars (FYS) program at Kennesaw State University (KSU) which is sponsored by the Office of Undergraduate Research (OUR). The goal of this program is to introduce first-year students to the undergraduate research experience. Students are encouraged to apply for projects they find interesting, regardless of whether the projects are in their majors. They serve as apprentices and are integrated into the research program of their Primary Investigator (PI), learning from both the PI and peers. This program helps students gain early research experience, which sets them on a path for future success. Research shows that early engagement in research is associated with positive outcomes, such as improved retention, progression, and graduation rates [13], [14] and enrollment in graduate school [15].

Self-powered Smart Helmet Project

The project involved collaboration between the Electrical and Computer Engineering (ECE) and Mechanical Engineering (ME) department at KSU. The aim was to design and fabricate a selfpowered smart safety helmet for bicyclists which could potentially reduce accidents and save lives. The helmet would integrate solar cells and micro wind turbines to power bright blinking LED lights integrated on the back side of the helmet, thus increasing nighttime visibility and safety. In addition, the helmet will have an integrated microcontroller and accelerometer sensor to gather information about potential falls and identify when such an incident had occurred.

FYS is available to all departments on campus and normally involves one or more students up to a maximum of three per project. The project starts around the middle of Fall and runs until the end of the Spring semester. For this project there were a total of nineteen applicants from various discipline. Based on the requirements for the project, it was decided that three students would be selected with mechanical and electrical engineering interests.

It should be noted that all students had little to no experience with the use of 3D modeling/CAD software, renewable energy harvesting or programming at the start of the project. Two students were assigned to handle the mechanical design and one to develop the necessary electronics and programming. An interdisciplinary project was specifically chosen to expose students to areas outside of their primary interest and to assess the impact, if any, on their chosen program of study at the end of the project.

Method

The Design Approach:

FYS students have limited expertise and exposure to engineering design. However, it was decided that the same format would be adopted as the senior design (Capstone) project that engineering students are expected to complete in their senior year. Although the design and engineering analysis would not be as extensive as compared to the Capstone project, the students were still expected to follow a similar methodology. This included tasks such as conducting a literature review, developing engineering specifications, engaging in brainstorming, performing calculations and basic simulations and also testing and validating their design. The design requirements were as follows:

- Develop a 3D printed bicycle helmet with embedded micro turbines and solar cells for energy harvesting
- Optimize the helmet geometry to harness sufficient energy to power all onboard electronics needed for crash detection and to power a LED light system to improve visibility and safety during low-light conditions
- Develop appropriate hardware and software to identify possible crashes scenarios such as a head on collision or a fall to the side.

Task Assignment

Due to the nature of the project, there was substantial overlap from both disciplines in order to solve the problem: To provide structure, the project was broken up into 4 primary areas:

- Mechanical design of helmet shell: SolidWorks (CAD) software was used to develop the helmet prototype. This design featured a slightly flattened top for efficient solar cell placement and an angular shape for enhanced airflow. The prototype was fabricated with the aid of a 3-D printer.
- Solar energy Harvesting: Thin-film solar cells (10) were used with a maximum power output of 827mW. This power output was managed by a dual-input charge controller that charges a 3.7v 1800mA lithium polymer battery, capable of lasting up to 22 hours on a full charge.
- Wind Energy Harvesting: Two Horizontal Axis Wind Turbines (HAWT), capable of producing up to 38mW at 10mph were used.
- Crash Detection: A model MPU6050 gyroscopic accelerometer was used to monitor realtime gyroscopic and acceleration forces, which is used to calculate the helmet angle via pitch and roll. When the G-force, angular velocity, or angle of the helmet exceed certain thresholds, an alert was generated, indicating a crash had occurred.

Final Design

Working collaboratively, the mechanical engineering students were able to successfully design and fabricate the Smart Helmet shown in Figure 1. The modeling software SolidWorks was used to produce the CAD model in Figure 1a and the design was printed (Figure 1b) using a 3-D printer. None of the students had prior experience using the software or printer.

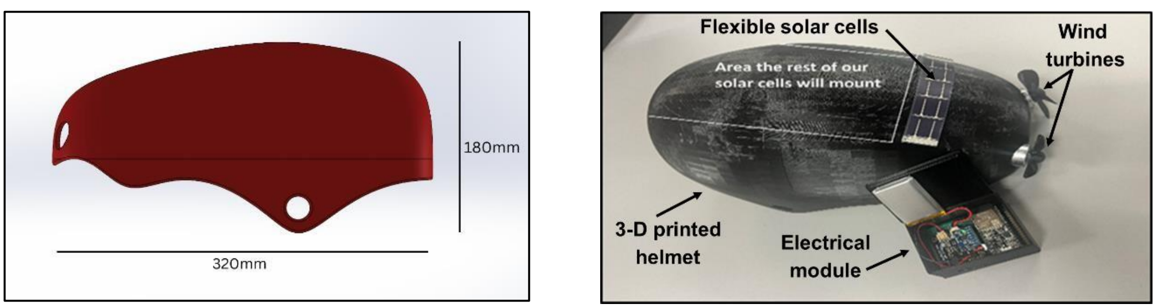

Figure 1: (a) SolidWorks Helmet CAD model, (b) 3-D printed helmet showing mounted wind turbines, solar cells and electrical module.

Additionally, they were tasked with learning to use appropriate test equipment such as a hotwire anemometer for measuring wind speed at various helmet locations. They were also required to develop the necessary experimental procedures for estimating power output from both the wind turbines and the solar array mounted to the helmet's surface.

The electrical engineering student was also able to successfully develop the necessary electrical circuit modules and housing unit as shown in Figure 2, for incorporating the accelerometer located within the helmet.

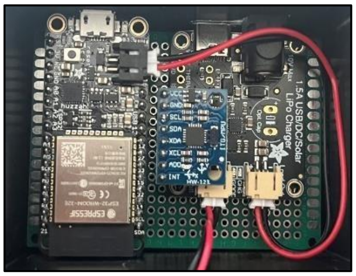

Figure 2: Electrical module and housing containing accelerometer.

Crash detection involved developing suitable algorithms and software code for analyzing the accelerometer's raw data to identify when the cyclist had experienced a fall or head on collision as shown in Figure 3. The electrical student had no significant programming experience or knowledge regarding the use or configuration of accelerometers.

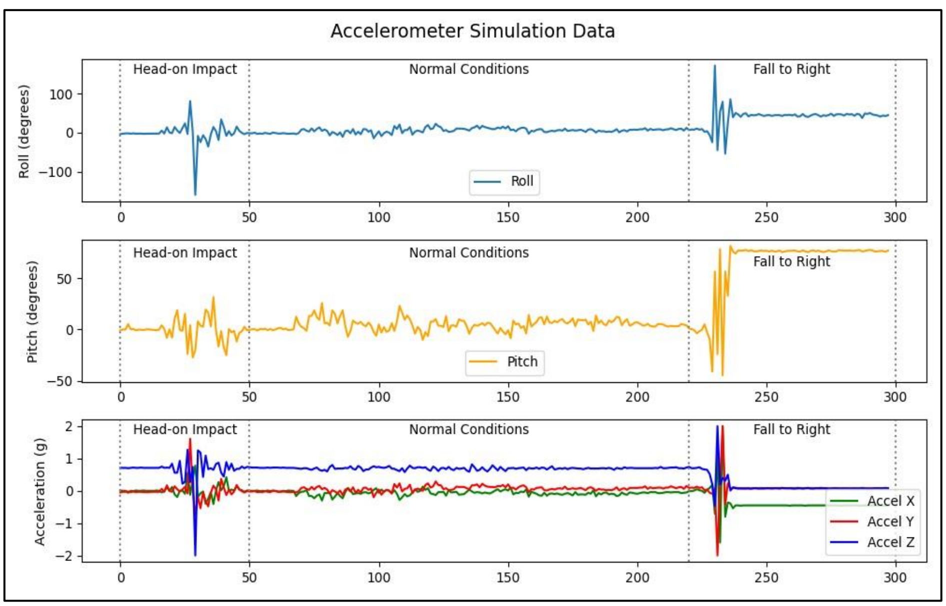

Figure 3: Signal detection for a head-on collision and a fall to the cyclist's right side.

The student team were able to complete their respective tasks to produce a functional Smart Helmet prototype. The FYS program requires all participating teams to present their research in the form of a poster at the Symposium of Student Scholars held each semester on the university's campus.

Impact and Assessment

A student survey was developed to assess the impact of the Smart Helmet project on their (1) interest in the engineering field, (2) engineering knowledge (3) desire to pursue further research (4) interest in pursuing higher level engineering courses (5) likelihood of recommending the FYS program to other students and also their overall experience. Each student was required to complete the survey questions shown in Table 1, at the end of the project.

Table 1: Smart Helmet project student survey

	Responses (% of Students)				
Questions	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Q1. The First Year Scholars Smart Helmet research project has increased your interest in the engineering field.	100				
Q2. Your involvement in the project has increased your engineering skills/knowledge	100				
Q3. Participation in Smart Helmet project has inspired you to continue to get involved in further research opportunities throughout your program of study	66.6	33.3			
Q4. The Smart Helmet research project has motivated you to successfully complete higher level engineering courses in order to gain more advanced analytical skills	100				
	Very Likely	Likely	Neutral	Somewhat Likely	Not Likely
Q5. How likely are you to recommend the First Year Scholars Program to other students or colleagues?	100				

Q6. Describe briefly your experience with the Smart Helmet project	• It was a great experience that helped me gain knowledge in not only research but also how to work with a team as a whole on an engineering project
	• It has been a fun informative experience, I have learned so much all while the program being low stress which was the biggest thing I was worried about. • I think this is a great program and this was a great project.

Results

The results of the survey indicate that the interdisciplinary engineering design project had an overwhelmingly positive impact on the first year students who participated in the program as indicated from the responses shown in Table 1. Students were motivated to further pursue undergraduate engineering research as they progressed through their study. They were also eager to enroll in higher level engineering courses as the project highlighted specific areas that would have benefited from a deeper understanding of more advanced concepts and design tools.

Several new skills were acquired from participation in the program such as the use of CAD software, 3-D printing and prototyping, algorithm development and programming, integration of wind and solar energy harvesting devices and the use of sensors such as anemometers and accelerometers. Additionally, they also gained intangible skills such as time management, communication and the ability to work effectively as a team on an interdisciplinary design project. Discussions with the student team indicated that a major motivating factor pursuing a STEMs career was exposure to new techniques and the skills they acquired in finding an appropriate solution

Conclusion and Future Work

The Smart Helmet project was successfully completed by the FYS team and they were able to attend and present a poster and prototype at the Symposium of Student Scholars. A second phase is anticipated with future teams working on optimizing the wind and solar output and also development of a software application to provide emergency alerts through the wearer's phone in the event of injury from a collision or fall. It is also expected that once an optimized design is realized, students will be involved in developing experiments would measure performance as well as safety in terms of impact from a potential crash.

An interdisciplinary project was intentionally selected for this program to investigate the impact on students' interest in the engineering field, and their ability to solve the problem at hand. Although they had limited experience in their chosen area of study, they were able to acquire the relevant knowledge and skills and work collaboratively outside their discipline, to produce a functional prototype. It is recognized that the sample size is small in this particular study as faculty were only allowed to supervise one team under this program. Based on the positive impacts that have been realized from the interdisciplinary project approach, it is expected that future projects of this nature will continue to be offered going forward that would provide a larger pool for analysis.

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