Board 138: Promoting Sustainable Innovation: Mechatronics and Collaborative Student Projects with Campus Sustainability Centers

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Promoting Sustainable Innovation: Mechatronics and Collaborative Student Projects with Campus Sustainability Centers

Abstract

In today's ever-changing world, where environmental concerns and innovation are on the rise, higher educational institutions play a crucial role in preparing the next generation of engineers and innovators to address pressing global challenges. This paper presents a three-year experience of a newly established mechanical engineering program with a mechatronics course, collaborating with our campus sustainability center to nurture sustainable innovation. This partnership has yielded a positive array of collaborative student projects showcasing mechatronics' tangible impact on sustainability.

Through diverse case studies, we spotlight successful projects that have appeared from this collaboration, along with the lessons learned. We emphasize mechatronics' transformative potential in addressing campus sustainability challenges and engaging students through experiential learning. Projects range from energy-efficient automation systems to eco-friendly solutions, illustrating students' creative problem-solving and the significance of interdisciplinary collaboration. Furthermore, the paper examines the challenges encountered by the newly developed mechatronics course for sustainable innovation. We also explore areas for improvement, including curriculum enhancements and more effective integration of sustainability principles, aiming to amplify the impact of such collaborations. This paper offers a valuable perspective for educators and institutions seeking to incorporate mechatronics into sustainability initiatives. It provides an opportunity for reflection on the journey of a newly developed program. We aim to inspire others to work together and encourage students to motivate others to join similar collaborations and empower students to lead sustainable innovations in their communities and beyond.

Introduction

In the face of escalating environmental concerns and the urgent need for sustainable solutions, the role of higher education institutions in fostering innovation and preparing future engineers is more critical than ever. The integration of sustainability into higher education, particularly through collaborations with sustainability centers, has been a topic of interest in recent literature [1-4]. Studies highlight the transformative potential of such collaborations in fostering a culture of sustainable innovation among students [5-7]. They emphasize the importance of multi-stakeholder collaborations [9,10] collective action, and interdisciplinarity [11], and the need for an intentionally collaborative culture. A study at the University of Évora concluded that students were primarily concerned with SDG (Sustainable Development Goals) 5 (gender equality), SDG 10 (reduced inequalities), SDG 11 (sustainable cities), SDG 16 (peace, justice, and strong intuitions), and more. However, all other SDGs were not as much of a concern, and in one case, SDG 6 (clean water and sanitation) did not appear in any course [12]. When engineering students at the University of Washington were asked about their personal sense of responsibility, 41% of student's responses did not apply to the modern concerns of sustainability. 32% of students envisioned sustainability in line with SDG 12 (responsible consumption and production). When compared to non-STEM students, STEM students expressed a greater personal interest in sustainability and its challenges [13].

However, as a newly developed engineering program, how to initiate and establish is relatively challenging. Therefore, this paper aims to share our journey, spotlighting the successful projects that have emerged from this collaboration, the challenges encountered along the way, and the lessons learned - a collaborative endeavor between a newly established mechanical engineering program and our campus sustainability center. We also discuss potential areas for improvement and future directions, with the goal of enhancing the integration of sustainability principles into the curriculum and amplifying the impact of such collaborations. By sharing our experiences and insights, we hope to provide a valuable resource for educators and institutions seeking to incorporate mechatronics into sustainability initiatives. More importantly, we aspire to inspire others to embark on similar collaborative endeavors, fostering a culture of sustainable innovation among students and empowering them to become change-makers in their communities and beyond.

The Introduction to Mechatronics course (MECH330) is a cornerstone of our curriculum, offered every fall semester and designed to engage mechanical engineering and industrial and systems engineering majors in hands-on, project-based learning. As an instructor in this newly developed program, my primary goal is to cultivate an engineering mindset among students, moving beyond theoretical knowledge to practical application in real-world scenarios. Recognizing the importance of sustainability in modern engineering practice, we have embraced a proactive approach to incorporate relevant sustainability projects into our curriculum. The collaboration with the Macoskey Center, a sustainability hub within our university, has been pivotal in achieving this objective. Our partnership began with a shared vision of fostering sustainability practices within our university and local communities. Initially, communication channels were established between the course instructor and the Center's management to explore potential collaboration opportunities. Over time, this relationship has evolved into a dynamic partnership, characterized by regular discussions, mutual project ideation, and joint initiatives aimed at advancing sustainable innovation.

Currently, about 20% of the project is research-related and is proposed by the instructor and other faculty. About 80% of the proposed project was from Macoskey Center. For the project to cooperate with the Center, the instructor communicates with the director to discuss potential projects, and arrangements are being made for a visit for the first two weeks. During the visit, the center director will introduce the Center's mission and present potential projects aligning with sustainability goals. This proactive approach allows students to acquaint themselves with the Center and make informed decisions about their project preferences. This collaborative engagement not only aligns with sustainability initiatives but also provides students with real-world problem-solving opportunities, enriching their academic experience. The focus of this collaboration is the mechatronics course, a multidisciplinary field that synergizes mechanical engineering, electronics, computer science, and control systems. Mechatronics, with its inherent interdisciplinary nature and emphasis on practical, hands-on learning, presents an ideal platform for integrating sustainability principles into engineering education.

Over the past three years, this partnership has catalyzed a series of student projects that not only demonstrate the practical applications of mechatronics but also underscore its potential to drive sustainable innovation. These projects, which span from energy-efficient automation systems to

eco-friendly solutions, serve as powerful testament to the creativity, problem-solving skills, and interdisciplinary collaboration of our students. Table 1 shows the past projects. These projects will be categorized based on three main categories: **Eco-friendly pest management, Enhance energy efficiency, and Resource conservation**. The student survey was conducted, and responses will be discussed in the student survey section.

Table 1. Past student projects proposed from sustainability center.

Selected Project	**2021**	**2022**	**2023**
Non-Lethal Smart Rodent Trap	x		
Smart Blinds with Home Assistant	x	x	
Greenhouse Irrigation System		x	x
Machine Learning Assisted Trail Camera		x	x
Low-Cost Particulate Matter/Air Quality Sensor			x
Blueberry Patch Pest Deterrent Mechanism			x

Student Project –

For each project, consisting of 3 to 4 students, the process begins with an introduction to potential topics and a visit to the Macoskey Center within the first two weeks. During this visit, students familiarize themselves with sustainability initiatives and gather inspiration for their projects. Subsequently, they engage in brainstorming sessions, where they justify their ideas and propose hypotheses, typically during the third week. Throughout the semester, each group presents their progress bi-weekly in class, receiving feedback from both peers and the instructor to enhance their projects. By the 15th week, groups conduct rehearsals to prepare for the final presentation. During the final exam week of the semester, faculty members from various engineering departments (Mechanical, Civil, Industrial and Systems, Petroleum and Natural Gas) and the Macoskey Center manager serve as judges to evaluate the projects.

Eco-Friendly Pest Management

Our dynamic collaboration with the Macoskey Center began with a dedicated focus on eco-friendly pest management, steering clear of harmful chemicals and lethal methods. In the fall of 2021, a student group proposed a non-lethal smart rodent trap designed to capture groundhogs, incorporating a notification mechanism to alert the manager upon successful capture so the

animal will not stay in the cage for a long period of time. Figure 1 shows the schematic of the electronics components used and the workflows by using the wireless transceiver to the communication to detect if the animal was caught in the trap. Building on this eco-conscious approach, in the fall of 2023, two separate groups proposed a solution to protect the blueberry patch in the center. Their eco-friendly strategy involved the strategic use of sound and light to deter animals that posed a threat to the blueberry crop. This ongoing commitment to eco-friendly pest management resonates with our collaborative efforts at the intersection of engineering and sustainability, contributing to the development and implementation of environmentally conscious practices within the Macoskey Center.

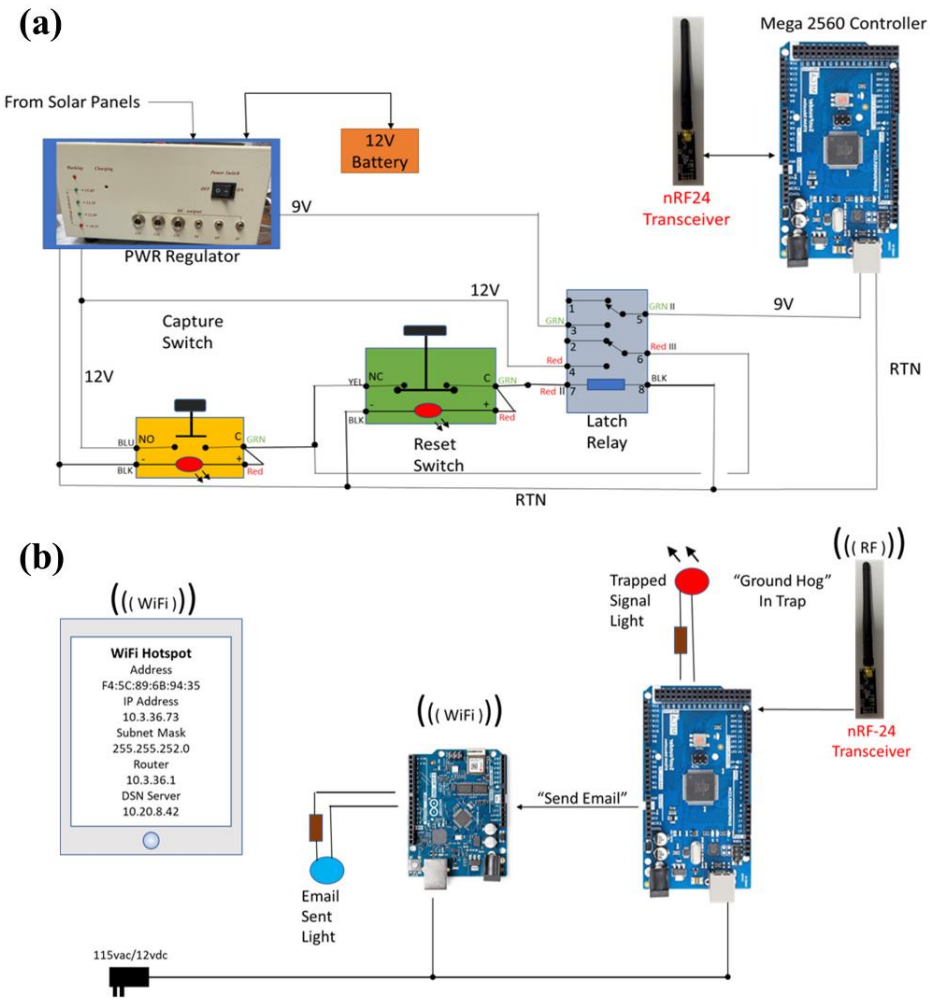

Figure 1 Schematic of rodent trip electronics communication via wireless (a) Trap with electronics transmitter in the garden (b) electronics with receiver in the center

Enhance Energy Efficiency

In our sustainability initiatives at the Macoskey Center, a key focus is on improving energy efficiency. During the academic years 2021 and 2022, our student teams took on the "Smart Blinds with Home Assistant" project to address the inefficiencies of manually controlled blinds, which led to unnecessary energy consumption. Extensive research confirmed the advantages of automated blinds in reducing energy usage and carbon footprint [12]. The identified needs were clear – to regulate temperature and enhance energy efficiency. The hypothesis suggested that automating and enabling remote control of the blinds would not only optimize energy utilization but also improve convenience.

Figure 2 depicts the proposed flow chart and schematic of hardware, software, and electronic components, resulting in the successful integration of the existing blinds with Home Assistant, a home automation platform. The outcomes showcased the effective integration of a temperature sensor, stepper motor, and servo motor, allowing remote control of the blinds via Wi-Fi from a phone or laptop. This mechatronics project's significance extends beyond its immediate impact on energy efficiency; it serves as a testament to the students' problem-solving capabilities and highlights the potential for automation in sustainable practices. Notably, both teams in 2022 and 2023 successfully controlled the blinds based on temperature sensors, utilizing stepper and servo motors through Home Assistant.

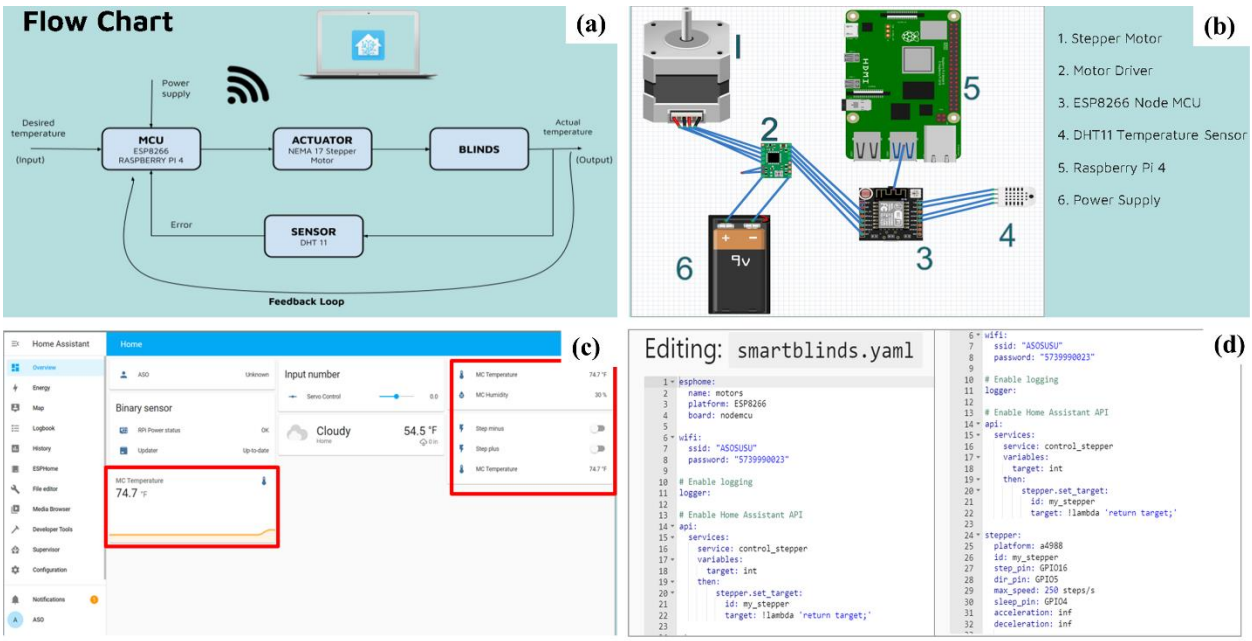

Figure 2. Smart Blinds with Home Assistant (a) Flow chart (b) schematic of electronic components (c) Home assistant user interface (d) home assistant programming

Resource Conservation

Resource conservation is a central focus of practical sustainability. In the academic years 2022 and 2023, students undertook the Greenhouse Irrigation System project to address challenges in the Macoskey Center's greenhouse. The existing manual watering system was inefficient and labor-intensive, leading to unnecessary water wastage. The proposed solution is to conserve resources effectively by providing water only when needed, aiming to rectify this issue and improve efficiency. This project involved a comprehensive reconstruction of the irrigation system design, with a focus on automation, improved mechanical design, and increased sustainability. Figure 3 illustrates the system's design and operation, showcasing the integration of Wi-Fi technology and the components responsible for automated watering. The final system achieved was a self-watering greenhouse with minimal maintenance requirements. The 2023 team successfully utilized Wi-Fi technology for seamless sensor communication and precise water control via solenoids (Figure 4), incorporating silicone seals to safeguard against outdoor elements. The current solution meets the needs of potted plants, and the developed approach not only automated the greenhouse irrigation system but also made significant contributions to resource conservation at the Macoskey Center.

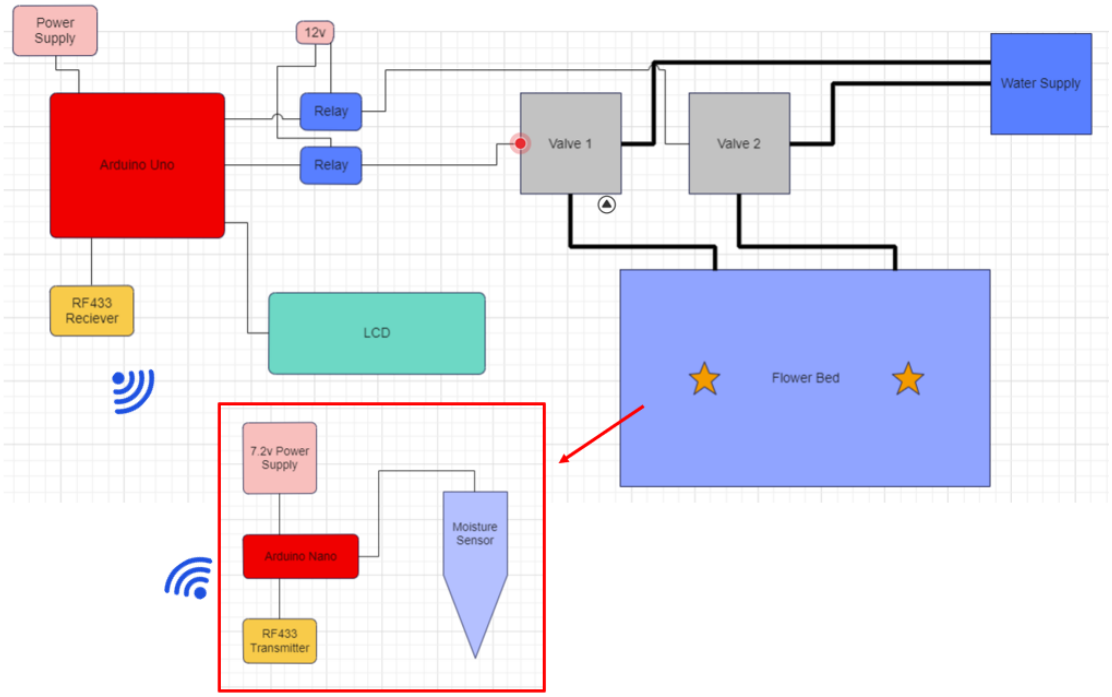

Figure 3. The schematic of irrigation process.

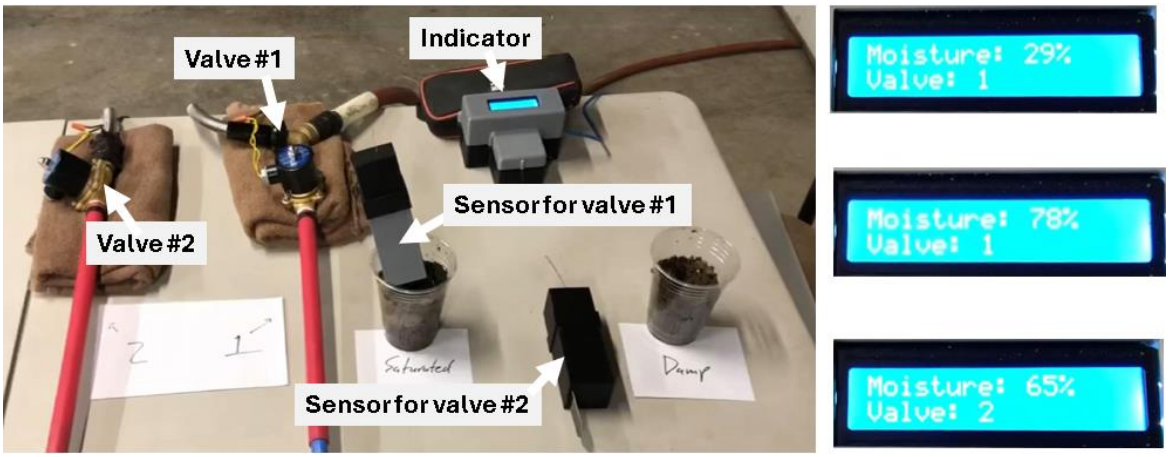

Figure 4. The prototype of the proposed system and demonstration

Student Survey

Methods - Survey Distribution

A survey was created using Google Forms and distributed in the classroom. Participation in the survey was entirely voluntary, and no compensation was offered to respondents. Responses were collected after class, with 28 subjects participating in the survey. It is worth noting that not all

respondents may have been involved in sustainability-related projects provided by the Macoskey Center, as the survey was open to all students. However, it is important to highlight that even students who were not directly involved in sustainability projects can still benefit from participating in bi-weekly meetings. These meetings provide opportunities for learning, influence, and feedback exchange, enhancing the student learning experience and cultivating sustainable problem-solving skills for future engineering challenges.

The survey was structured into Four distinct sections:

1. The survey was structured into three distinct sections: General Information

    1.1 What is your current academic year?
    □ Freshman □ Sophomore □ Junior □ Senior
    1.2 How familiar are you with the collaboration between the Mechatronics Course and the Macoskey Center?
    □ Not familiar at all □ Somewhat familiar □ Moderately familiar □ Very familiar
    □ Extremely familiar
    1.3 Have you participated in any projects or activities in the course that collaborated with the Macoskey Center?
    □ No □ ENGR120 Engineering Design Tools □ ME330 Introduction to Mechatronics
    □ Others

2. Impact on Learning Experience. Please rate the impact of these projects/activities on the following aspects of your learning experience. (scale: 1-5, 1 being least impactful and 5 being highly impactful)

    2.1 Practical application of Mechatronics knowledge
    being least impactful 1 2 3 4 5 being highly impactful
    2.2 Understanding of sustainability principles
    being least impactful 1 2 3 4 5 being highly impactful
    2.3 Interdisciplinary learning
    being least impactful 1 2 3 4 5 being highly impactful
    2.4 Problem-solving skills development
    being least impactful 1 2 3 4 5 being highly impactful

3. Future Impact and Involvement

    3.1 To what extent has this collaboration influenced your interest in pursuing further projects or studies related to sustainability or mechatronics?
    □ Greatly increased interest □ Somewhat increased interest □ No impact
    □ Decreased interest

3.2 Would you be interested in more involvement or opportunities related to sustainability within the Mechatronics Course in the future?
□ Yes, definitely □ Maybe □ No, not interested

4. Future Impact and Involvement (Open question)

4.1 What do you perceive as the main strengths of this collaboration?
4.2 What improvements, if any, would you suggest for enhancing the impact of this collaboration?
4.3 Is there anything else you would like to share about your experience or thoughts regarding the collaboration between the Mechatronics Course and Macoskey Center?

Survey Results

General Information

The instructor conducted a survey to gauge the familiarity and participation of students in the collaboration between the Mechatronics Course and the Macoskey Center. The survey consisted of two questions. The first question asked about the students' familiarity with the collaboration, and the second question asked if they had participated in any projects or activities because of this collaboration.

Figure 5 illustrates the results of the first question, revealing that 71.5% of students reported being either very familiar or extremely familiar with the collaboration with the Macoskey Center. Interestingly, even students who did not participate in the projects demonstrated awareness of the collaboration. Throughout the semester, each group conducted bi-weekly presentations to showcase their progress, providing opportunities for other groups to learn about different technologies and strategies for promoting sustainability. Analyzing responses to the second question, shown in Figure 6, revealed that 3.6% of respondents selected 'NA,' indicating no participation in the listed courses. Of the respondents, 21.4% had participated in the 'MECH 340 Heat Transfer' course as part of the collaboration, while a significant majority (85.7%) had engaged in the 'MECH 330 Introduction to Mechatronics' course, indicating substantial involvement. Additionally, more than half of the respondents (53.6%) had participated in the 'ENGR 120 Engineering Design Tools' course as a result of the collaboration.

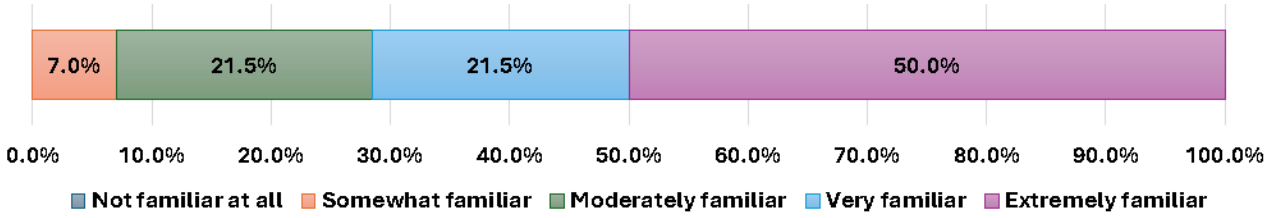

Figure 5. Survey general question 1: How familiar are you with the collaboration between the Mechatronics Course and the Macoskey Center?

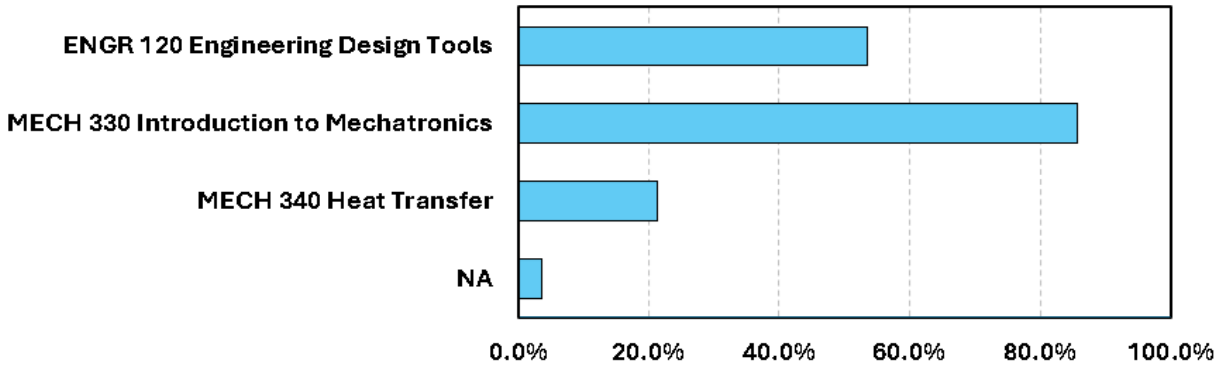

Figure 6. Survey general question 2: Have you participated in any projects or activities in the course that collaborated with the Macoskey Center?

Impact on Learning Experience

The second part of the survey is to understand the impact of projects and activities resulting from the collaboration between the Mechatronics Course and the Macoskey Center on students' learning experience. The impact was rated on a scale of 1-5, with 1 being least impactful and 5 being highly impactful.

When we analyzed the responses shown in Figure 7, we found that none of the respondents rated the practical application of Mechatronics knowledge as 1 or 2. In fact, a significant majority, 82.2% of respondents, found it highly impactful, rating it as 4 or 5. Similarly, for the understanding of sustainability principles, none of the respondents rated it as 1 or 2. Most respondents, 67.9%, rated it as 3 or above, indicating a moderate to high impact. For

interdisciplinary learning, none of the respondents rated it as 1, and only a small percentage, 3.7%, rated it as 2. A significant majority, 78.6% of respondents, found it highly impactful, rating it as 4 or 5. Finally, for problem-solving skills development, none of the respondents rated it as 1 or 3, and only a small percentage, 3.6%, rated it as 2. A significant majority, 96.4% of respondents, found it highly impactful, rating it as 4 or 5.

These results suggest that the projects and activities resulting from the collaboration have had a significant positive impact on the students' learning experience, particularly in terms of practical application of Mechatronics knowledge and problem-solving skills development.

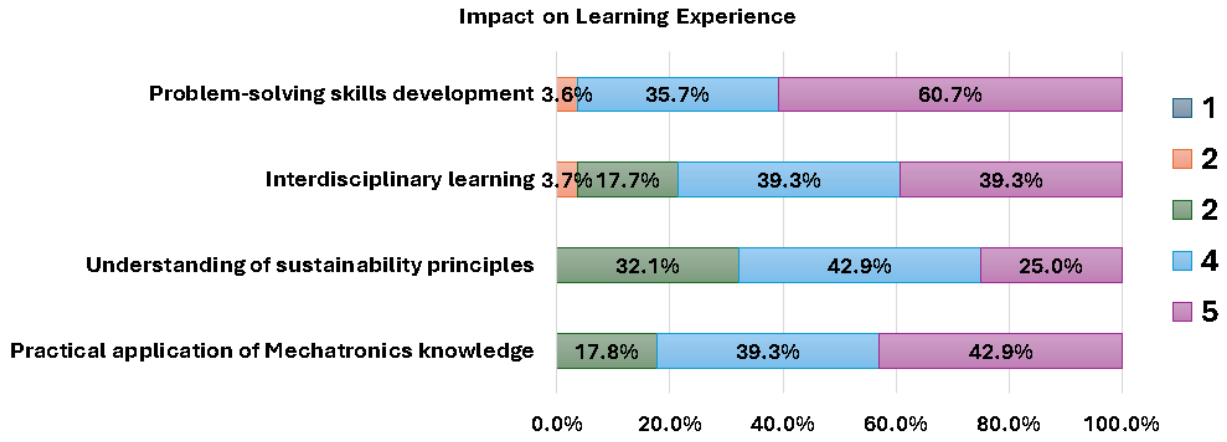

Figure 7. Survey result: the impact of these projects/activities on the following aspects of your learning experience (scale: 1-5, 1 being least impactful and 5 being highly impactful)

Future Impact and Involvement

The third part of the survey is to know to what extent this collaboration influenced your interest in pursuing further projects (Figure 8). Approximately 96.4% of students reported an increased interest in pursuing further projects or studies related to sustainability or mechatronics because of this collaboration. This includes 64.3% of students who reported a somewhat increased interest and 32.1% who reported a greatly increased interest. Only one student did not perceive any influence on their interest towards sustainability-related projects, indicating a highly positive impact overall. This data strongly suggests that collaborations with the Macoskey Center significantly enhance student engagement and interest in sustainability and mechatronics.

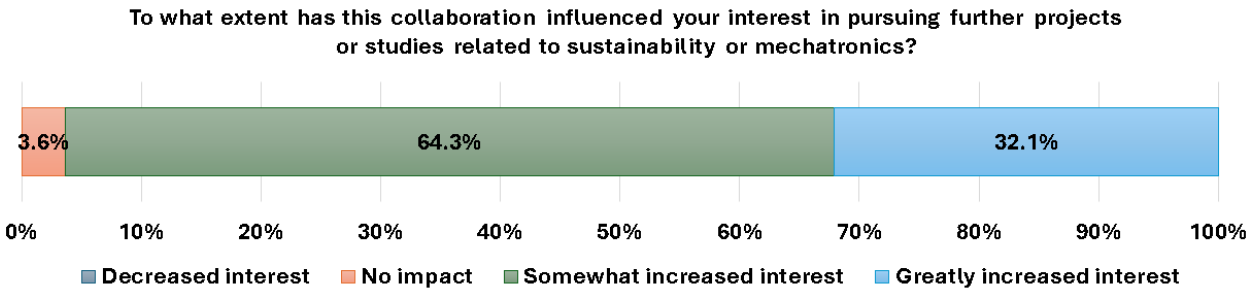

Figure 8. To what extent has this collaboration influenced your interest in pursuing further projects or studies related to sustainability or mechatronics?

Based on the survey results shown in Figure 9, a significant majority of students (64.3%) are interested in more involvement or opportunities related to sustainability within the Mechatronics Course in the future. Additionally, 32.1% consider it as an option. Only a small fraction (3.6%) is not interested. This indicates a strong inclination towards incorporating sustainability-related projects and opportunities in the course.

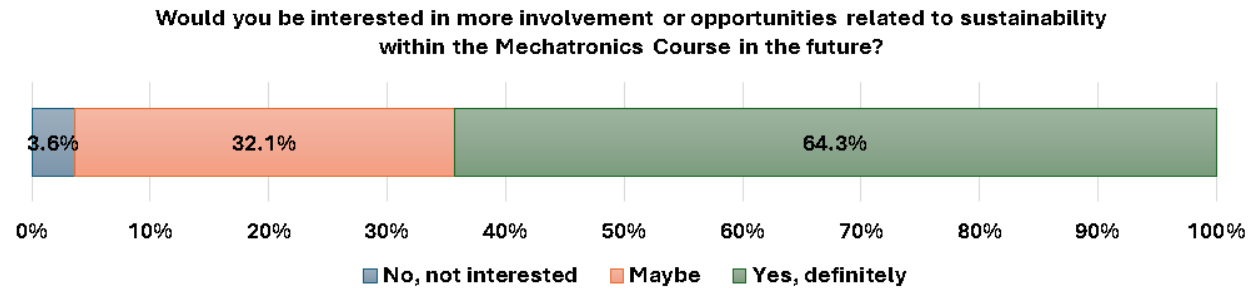

Figure 9. Would you be interested in more involvement or opportunities related to sustainability within the Mechatronics Course in the future?

Survey Respondent Comments

In addition to scoring mechatronics concepts, the survey asked the following three questions to the respondents:

1. What do you perceive as the main strengths of this collaboration?
2. What improvements, if any, would you suggest for enhancing the impact of this collaboration?

3. Is there anything else you would like to share about your experience or thoughts regarding the collaboration between the Mechatronics Course and Macoskey Center?

For the first question, we explore the perceived strengths of a collaborative educational initiative. Participants provided open-ended responses, which helped us understand their viewpoints better. Through thematic analysis, we identified key themes related to sustainability, hands-on experiences, problem-solving, teamwork, and mechatronics implementation.

Key themes included:

Sustainability: Participants appreciated the integration of sustainability principles.
Hands-on Experience: The practical, hands-on aspect resonated positively.
Problem-solving and Application: Respondents valued applying engineering knowledge to real-world problems.
Teamwork: Collaborative work was recognized as a strength.
Mechatronics Implementation: Some participants found this unique aspect intriguing.

The result:

Sustainability and Applied Engineering (17.86%): Participants appreciated the integration of sustainability principles with applied engineering concepts. This dual focus resonated positively.
Hands-on Experience and Real-world Application (25%): The practical, hands-on nature of the collaboration stood out. Participants valued opportunities to build circuits, design mechanisms, and apply knowledge in real-world contexts.
Problem-solving, Teamwork, and Critical Thinking (21.43%): Collaborative problem-solving and critical thinking were recognized as key strengths. Working in teams and applying analytical skills were highly regarded.
Mechatronics Implementation and Career Preparation (7.14%): Although less frequent, the inclusion of mechatronics intrigued some participants. They saw it as a pathway to future career steps.

Our findings highlight the importance of sustainability, hands-on experiences, and practical application in collaborative learning. Educators can leverage these insights to enhance course design and foster meaningful student engagement. Future research could explore the impact of these strengths on long-term learning outcomes.

For the second question, we grouped the responses into several thematic categories based on participants' suggestions:

Practical Application and Real-world Relevance (42.86%): Participants emphasized making projects more practical and applicable. Applying student-created solutions in real-world scenarios was a recurring theme. Displaying project outcomes at the Macoskey Center could showcase program strengths.

Time Allocation (21.43%):

- Several respondents requested more time to work on projects during class.
- Allocating sufficient time for project development emerged as a common need.

Diverse Project Options (7.14%):

- Offering a wider range of project choices was recommended.
- Providing diverse options could enhance student engagement.

Collaboration and Communication (10.71%):

- Participants desired increased collaboration with the Macoskey Center director.
- Facilitating communication and guidance was important.

Resource Allocation (10.71%):

- A few participants suggested allocating a budget for more effective project implementation.
- Adequate resources can lead to impactful outcomes.

Overall, the responses highlight the importance of real-world application, collaboration, time management, and practical considerations such as budget and project complexity in optimizing the educational experience within the collaborative framework of the course. These insights can inform future project planning and execution to better meet the needs and expectations of students.

For the third question, 17 students responded to the question. We grouped the responses into several thematic categories based on participants' suggestions:

Positive Experience and Learning (17.6%):

"Very fun and I learned a lot."
"It was a great experience and we had hands-on experience in engineering!"
"It was great to combine our engineering practices with a different field."

Concerns about Time Management and Course Structure (11.8%):

"We were rushed between class and multiple projects."
"50% of the course grade seems a little high."

Suggestions for Improvement (11.8%):

"I think in order for these projects to be successful or ready to be implemented checks throughout the semester need to be done and more strict."
"When we did our project we thought mechatronics didn't fit into our project too well with the chicken coop."

No Additional Comments or N/A (23.5%):

Overall, the majority of responses express a positive experience and learning outcome from the collaboration between the Mechatronics Course and Macoskey Center. However, there are also some concerns raised about time management, course structure, and suggestions for improvement in project implementation. These insights can be valuable for refining the collaboration process and enhancing student experiences in future iterations of the course.

Conclusion

The collaboration between our mechanical engineering program and the Macoskey Center has yielded significant benefits for both sustainability initiatives and student learning experiences. Through engaging projects, students have demonstrated their capacity to apply mechatronics principles to real-world challenges, contributing to the advancement of sustainable practices on our campus. While our partnership has been fruitful, there are opportunities for further enhancement. Suggestions such as increasing project budgets, diversifying project options, and allocating additional class time for project development have been proposed based on student feedback. These improvements are intended to maximize the impact of our collaboration and provide students with even more meaningful learning opportunities. Overall, the positive feedback from students underscores the value of interdisciplinary, hands-on learning experiences in promoting sustainable innovation. Through continued collaboration and improvement, we endeavor to inspire future generations of engineers to address sustainability challenges in their communities and beyond.

Acknowledgement

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