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Research Article

Greening the Campus: Strategies for Sustainable Transformation in Higher Education

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Abstract
This article investigates strategies for achieving sustainable transformation within higher education, specifically centered on 'Greening the Campus.' As environmental challenges intensify, universities are pivotal in promoting sustainable practices across their operations and educational frameworks. This study highlights successful initiatives implemented by various institutions, particularly within engineering disciplines, showcasing best practices while addressing the challenges faced and the overall effects on campus culture and community engagement. Utilising a mixed research approach, which includes a thorough literature review and case studies of universities recognised for their sustainability efforts, we identify several key strategies. The study is a case study of the electrical and mechanical engineering departments, and 30 students and 10 lecturers were sampled. These include increasing energy efficiency, encouraging sustainable transportation solutions, and infusing sustainability principles into engineering curricula. Findings reveal that institutions prioritizing sustainability not only minimise their ecological footprint but also cultivate a heightened sense of awareness and responsibility among students and staff. Furthermore, the discussion emphasises the critical role of leadership commitment and active stakeholder involvement in advancing sustainable initiatives, particularly within engineering programs. The conclusion advocates for a comprehensive approach to sustainable transformation, urging higher education institutions to embed these strategies within their culture and curricula. By doing so, universities can contribute meaningfully to global sustainability objectives while preparing students to tackle pressing environmental challenges. The overarching message is clear: a commitment to greening the campus fosters an environment that not only supports ecological stewardship but also inspires the next generation of engineers and leaders to face global sustainability challenges head-on.

Keywords: Curriculum Integration, Environmental Practices, Engineering Sustainability, Greening the Campus, Higher Education, Sustainable Transformation

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1. INTRODUCTION

The escalating environmental crises manifested in climate change, biodiversity loss, and resource depletion are compelling higher education institutions to reassess their traditional operational models and embrace more sustainable practices (Steele & Rickards, 2021). This challenge is particularly pronounced within engineering disciplines, which inherently involve significant resource consumption and have far-reaching impacts on environmental sustainability. Engineering programs are not only responsible for educating the next generation of engineers but also play a crucial role in designing, implementing, and advocating for solutions that mitigate environmental impact (Foo, 2013; Seager, et al., 2012). As influential entities in society, universities have a unique opportunity to serve as leaders in sustainable transformation. Through initiatives encompassed by the concept of 'Greening the Campus,' educational institutions can set a precedent for environmental stewardship (Jabbour, et al., 2013). These initiatives involve adopting

sustainable practices in campus operations, rethinking infrastructure design, and fostering a culture of sustainability that extends beyond the university walls into the wider community. Engaging students and faculty in these initiatives not only helps reduce the carbon footprint of the campus but also instills a sense of responsibility and activism among those who will become future leaders and innovators in various fields, particularly in engineering (Khanal, 2024; Klein, et al., 2021).

This shift toward sustainable practices represents more than just an environmental imperative; it is also a profound educational opportunity. Engineering education can be transformed to emphasize sustainability as a core value, enabling students to explore innovative solutions for real-world challenges (Tejedor, et al., 2018). By integrating sustainability into the curriculum, engineering programs can empower students to think critically about the environmental impacts of their designs, encouraging them to innovate in sustainable technologies, renewable energy systems, and eco-friendly materials. Ultimately, this approach nurtures a new generation of problem solvers who are equipped to address the complex environmental challenges facing the world today. By prioritising sustainability in engineering education, universities not only contribute to global sustainability goals but also fulfill their mission of preparing informed, responsible citizens capable of driving positive change in their communities and beyond.

1.1. Literature Review

1.1.1. Importance of Sustainability in Engineering Education

Sustainability has emerged as a pivotal aspect of education for engineering students. Surveys indicate that both students and lecturers recognize sustainability as integral to their engineering training (Sharma, et al., 2017). This encompasses a wide range of practices for electrical engineering students, including energy efficiency, renewable energy integration, and a response to evolving regulatory and societal demands for cleaner technologies (Al-Shetwi, 2022). Many students perceive knowledge of sustainable practices as essential for their future careers, viewing the shift towards greener technologies as a necessity, rather than a trend (Laszlo & Zhexembayeva, 2017; Rugarcia, et al., 2000).

Mechanical engineering students echo these sentiments by emphasizing design principles that prioritize durability, recyclability, and energy efficiency (Yousif & Moalosi, 2024). Their education equips them with the skills to develop systems and products that meet current societal needs without compromising future generations. Lecturers reinforce the view that sustainability is a fundamental principle rather than a supplementary topic, expressing a duty to nurture environmentally conscious and ethically responsible engineers (Beringer & AdomBent, 2008). This aligns with literature suggesting that institutions embracing sustainability foster innovation and critical thinking, preparing students to contribute meaningfully to societal advancements. Engineering education need to adapt to address the challenges posed by climate change and resource depletion (Ashford, 2004; Reid, 2019).

1.1.2. Influence of Sustainability Initiatives on Institutional Reputation

Sustainability initiatives significantly impact a university's reputation, particularly in the context of electrical and mechanical engineering programs. Many students state that robust sustainability practices influenced their choice of institution, reinforcing a connection to a forward-thinking community focused on positive change. Several studies suggest that while students appreciate sustainability efforts, they also seek further engagement and more comprehensive integration in their education (Bryson & Hand, 2007; Kahu & Nelson, 2018; Zsoka, et al., 2013). Lecturers note that these initiatives enhance institutional reputation by demonstrating a commitment to social responsibility, leading to partnerships with industry and government agencies. Universities with strong sustainability programs attract leading faculty and researchers, enriching the academic environment and providing students with access to cutting-edge research. Interdisciplinary learning improves 21st century skill such as problem-solving abilities and equips students to tackle complex challenges (Harvie, 2020; Tariq, 2024).

Additionally, institutions recognised for sustainability efforts often perform better in rankings that measure university sustainability, creating a cycle where a strong reputation increases enrollment, funding, and further innovations in sustainability. This positive momentum underscores the literature's assertion

that integrating sustainability into the educational framework offers significant benefits, preparing graduates for a landscape increasingly governed by environmental considerations.

1.1.3. Courses/Modules and Projects Emphasizing Sustainability Principles

Both electrical and mechanical engineering programs have increasingly adopted sustainability principles into their curricula (Thurer, et al., 2018). Courses such as Renewable Energy Systems, Sustainable Electrical Energy Systems, Electric Vehicle Technology, and Sustainable Power Generation allow electrical engineering students to explore renewable technologies through hands-on projects, such as designing solar energy systems for local communities (Braun, 2009). Mechanical engineering students engage in similar activities, too, with programs focused on sustainable product design and energy systems that prioritize life cycle assessments to minimise environmental impact. The mechanical engineering courses can be categorised as Sustainable Design and Manufacturing, Energy Efficiency and Conservation, and Renewable Energy Systems (Ruiz-Rivas, et al., 2020). The students advocate for a more integrated approach to teaching sustainability in engineering programs (Gutierrez-Bucheli, et al., 2022; Quelhas, et al., 2019).

Lecturers underscore the value of integrated design principles and sustainable materials science in the curriculum. By collaborating on interdisciplinary capstone projects, students learn to address engineering problems holistically and consider environmental implications in their designs. This comprehensive approach prepares future engineers to confront pressing environmental challenges while promoting a culture of sustainability within their respective fields.

1.1.4. Education and Preparedness for Addressing Real-World Challenges

Engineering education plays a crucial role in preparing students to tackle real-world challenges related to climate change and resource conservation. Students increasingly recognize that their curriculum includes a focus on systems thinking and sustainability-oriented problem-solving. For instance, electrical engineering coursework incorporates renewable energy technologies, while mechanical engineering students apply energy efficiency concepts in real-world scenarios. It is therefore important to prepare engineering students to tackle real-world issues through applicable skills and knowledge (Shuman, et al., 2005). Through collaborative, hands-on learning experiences, students develop essential skills and critical thinking abilities needed to address global sustainability issues. Lecturers reinforce the importance of using real-world data in their teachings and encourage students to think beyond the classroom, ensuring they are ready to face environmental challenges professionally. Experiential learning increases student engagement and strengthens theoretical concepts (Kolb & Kolb, 2005).

1.1.6. Projects and Case Studies Integrating Sustainability Concepts

Students and lecturers recognize specific projects and case studies that effectively incorporate sustainability within engineering education. In electrical engineering, projects often include designing energy management systems and collaborating with local municipalities to enhance renewable energy utilization. Mechanical engineering students also engage in efforts to retrofit existing systems for improved energy efficiency, showcasing the practical application of their learning. These projects not only help students develop technical skills but also foster a mindset of social responsibility. Interdisciplinary collaborations are emphasized, where students learn to appreciate diverse perspectives and focus on holistic solutions that meet economic, environmental, and social needs in community development.

1.1.7. Essentials for Future Engineers in Sustainable Materials Science

As they prepare for the professional landscape, both students and lecturers stress essential values for future engineers centered on sustainability. Key values highlighted include environmental stewardship, interdisciplinary collaboration, innovative problem-solving, and ethical responsibility. These values guide students as they aspire to work in sectors such as renewable energy, sustainable manufacturing, and resource management. Students envision applying these principles across various sectors, emphasizing the

integration of renewable energy solutions, lifecycle analysis, and smart technologies to promote efficiency and reduce environmental impact. The commitment to sustainability is evident as students increasingly recognize the role of energy management in their education and future careers.

1.1.8. Case Studies in Curricular Integration of Sustainability

The literature also outlines successful case studies where engineering programs have effectively integrated sustainability into their curricula. Initiatives such as university-wide sustainability programs, capstone projects with community impact, and utilizing campus infrastructures as living labs provide frameworks for students to engage with sustainability concepts meaningfully. Feedback underscores the significance of interdisciplinary approaches and collaboration across engineering disciplines, highlighting how these efforts enrich students' understanding of sustainability challenges while fostering a community-oriented mindset. The challenges to integrating sustainability in education effectively are resistance to change, lack of sustainability objectives, and lack of resources, lack of training, lack of alignment of sustainability education with the industry needs (Staniskis & Katiliute, 2016; Leifler & Dahlin, 2020; Rampasso, et al., 2019a). The literature reinforces that integrating sustainability into engineering education equips future engineers with the necessary skills and values to address critical environmental challenges, thus preparing them to contribute meaningfully to a more sustainable future. The students perceived that sustainability is very important in engineering education (Rampasso, et al., 2019b).

Overall, the literature demonstrates that while electrical and mechanical engineering students and lecturers appreciate existing sustainability initiatives on campus, substantial opportunities for improvement remain. Enhancing curricular integration, expanding hands-on learning experiences, fostering connections with local communities, and encouraging interdisciplinary collaboration are areas that could further enrich students' educational experiences. The case studies illustrate successful models of sustainability integration, creating collaborative environments where students can actively engage in addressing contemporary environmental challenges. By building on these experiences, institutions can cultivate future engineers who are not only adept in technical skills but also committed to leading sustainable practices in their careers.

2. METHODS

This study employed a mixed approach, incorporating a literature review and case studies of selected university engineering departments recognized for their sustainability efforts, with a specific focus on engineering departments. Interviews were conducted with campus sustainability engineering faculty lecturers, and students involved in sustainability projects to gather qualitative data on different engineering-specific initiatives that contribute to greening the campus. The research questions fall under perceptions of sustainability, curriculum integration, real-world application, future leadership, and feedback on initiatives. Through these questions, we can gain valuable insights from both lecturers and students about the effectiveness of current sustainability strategies in higher education and explore new avenues for enhancing the educational experience while promoting sustainable practices.

Quantitative analysis in the context of the survey data presented involves several important components and methodologies that can be employed to interpret the collected data effectively. For students, the research questions will focus on their perceptions of sustainability and related educational practices, drawing on quantitative data to provide measurable insights. Areas of inquiry will include their awareness of sustainability topics within the curriculum, the degree to which they feel these topics are integrated into their courses, and how they perceive the applicability of these concepts to real-world situations. Additionally, we will gather data on students' views regarding their preparedness for future leadership roles in sustainability and their feedback on existing initiatives aimed at promoting sustainable practices.

By utilizing quantitative data such as survey responses that can quantify levels of agreement, satisfaction, or engagement, we can derive statistically significant insights into students' experiences. For example, we might analyze responses to questions like: How often do you encounter real-world applications of sustainability in your coursework? To what extent do you feel prepared to take on leadership roles in sustainability after graduation? This quantitative approach allows us to identify trends and correlations,

providing a clearer picture of how students perceive sustainability initiatives in their educational journey. Ultimately, these insights will contribute to evaluating the effectiveness of current strategies and uncovering new opportunities for enhancing the educational experience while promoting sustainable practices.

2.1. Research Design

A structured questionnaire was used with closed-ended questions, often using Likert scales (e.g., 'Very Important,' 'Important,' etc.) or yes/no responses. This design allows for easy quantification of responses.

2.2. Participants

The population constitute on all the students and lecturers (L) in electrical and mechanical engineering. The analysis is based on a sample size total of 10 lecturers (with 5 lecturers from electrical engineering (E) and 5 from mechanical engineering (M), 30 students, with 15 students from electrical engineering (E) and 15 from mechanical engineering (M). This provides a balanced comparison across the two engineering disciplines.

2.3. Research Instruments

The study utilised a mixed-methods approach, incorporating both qualitative and quantitative research instruments to gather comprehensive data. An interview guide was developed for lecturers to facilitate in-depth discussions about their perspectives, experiences, and insights related to the research topic. This qualitative tool aimed to capture nuanced information that could shed light on the lecturers' teaching methodologies, challenges, and the impact of specific educational practices. Concurrently, a survey questionnaire was administered to students, designed to collect quantitative data on their perceptions and experiences in the educational environment. The questionnaire included Likert-scale questions, multiple-choice items, and open-ended questions to allow for both statistical analysis and rich, descriptive feedback. Together, these instruments provided a holistic understanding of the educational landscape, enabling the researchers to triangulate findings and develop a more robust analysis of the data collected from both lecturers and students.

2.4. Procedures

Frequency counts the number of responses for each category of answers were recorded and compiled into frequency counts (e.g., the number of students who categorized sustainability as 'Very Important. Percentages indicate that the frequency counts were converted into percentages to help illustrate the proportion of respondents in each category. For example, if 20 out of 30 students said sustainability is 'Very Important,' this represents a % of the respondents. Visualization Techniques: Tables were suggested for visual representation of the data, allowing for a quick reference to how different categories of responses compare to one another.

2.5. Data Analysis

In a comparative analysis, responses from both electrical and mechanical students and lecturers can be analyzed collectively or compared between the two groups to identify similarities and differences in perceptions, curricular integration, and future leadership regarding sustainability. Data collected after interviewing the lecturers was analysed thematically using codes. Themes offer a framework for structuring and presenting the researcher's analytical insights (Clarke & Braun, 2017). The analysis employed in the survey included structured data collection through a well-designed questionnaire, descriptive statistics summarizing frequencies and percentages, visualization of results using tables, and the potential for inferential statistics to deepen the analysis of data warranted. Overally, the quantitative analysis provides a clear, data-driven picture of students' perceptions of sustainability in their engineering education.

3. RESULTS

3.1. Qualitative Results from Lecturers in Electrical and Mechanical Engineering were Interviewed Regarding the Greening in Their Teaching

On the importance of sustainability in education, L1E, L2E, L3E, L4M, and L5M emphasized that sustainability is crucial for engineering education, linking it to ethical responsibility and the relevance of engineers in addressing global challenges. L4E, L5E, L1M, L2M, and L3M noted that understanding sustainability is essential for ensuring safe and effective engineering solutions in the future.

3.1.1. Influence on University Reputation

L1E, L2E, L4M, and L5M agreed that sustainability initiatives positively enhance the university's reputation by attracting students and partnerships. L5E, and L2M mentioned that sustainability initiatives have positioned the university as a leader in engineering education.

> L3E: *'Universities can boost their reputation by enhancing curriculum quality and improving graduate employability through practical skill development.'*
>
> L4E: *'Universities can elevate their reputation through increased research opportunities and strong industry partnerships that promote innovation.'*
>
> L1M: *'Universities attract students interested in business and build a positive reputation through successful alumni by emphasising strongly on programs.'*
>
> L3M: *'Universities that excel in engineering education programs demonstrate advanced management practices and gain recognition through accreditation, enhancing their overall academic prestige.'*

On ways students believe the university can improve sustainability practices on campus, a total of 45 students (22 Electrical, 23 Mechanical) suggested enhanced waste management systems, improving public transportation options, and increasing green spaces on campus.

3.1.2. Curricular Integration for Specific Courses/Modules and Projects

L1E and L4E highlighted courses such as 'Renewable Energy Systems' and 'Sustainable Electrical Design. L3E and L1M, L5M mentioned courses like 'Sustainable Mechanical Engineering Design' and projects involving wind turbine design as examples of integrating sustainability principles into the curriculum. L5E and L4M both noted that capstone projects often focus on sustainability, allowing students to apply concepts learned throughout their studies.

> L2E: *'Integrating our environmental science module with social studies could provide a more holistic view of sustainability and its societal impacts.'*
>
> L2M: *'It would be beneficial to combine our operations management course with a sustainability module to learn how sustainable practices can improve supply chain efficiency.'*
>
> L3M: *'I believe merging our strategic management course with sustainability frameworks would help us understand how to effectively incorporate sustainable practices into long-term business strategies.'*

Integrated Design Principles

All LEs and LMs noted that integrated design principles and sustainable materials are fundamental aspects of their coursework. They cited projects requiring life-cycle assessments and the use of eco-friendly materials.

3.1.3. Real-World Application Preparation for Challenges

L1E emphasized that education equips students to tackle real-world challenges, particularly climate change and resource conservation. L5M specifically mentioned that practical labs and fieldwork enable students to engage meaningfully with these issues.

> L2E: *'I believe our current coursework lacks real-world context. It would be helpful to have more projects that focus on solving actual sustainability issues in our communities, which would give us a better understanding of the challenges we face.'*
>
> L3E: *'While we study theoretical frameworks, I think we need to implement more practical experiences, such as internships or partnerships with local organizations focused on sustainability. This would help bridge the gap between theory and practice.'*
>
> L4E: *'One key area for improvement is simulation-based learning. Creating simulations related to environmental impacts and resource management can better prepare us for real-world decision-making in sustainability.'*
>
> L5E: *'We should be exposed to sustainability challenges through case studies of companies that successfully integrated sustainable practices. This exposure would give us insightful lessons on what works and what doesn't in real-world applications.'*
>
> L1M: *'Our management courses focus too much on traditional models. Integrating modules on sustainable management practices and how to lead sustainability initiatives would better prepare us for the challenges in the industry.'*
>
> L2M: *'I think we must have workshops that focus on problem-solving within sustainability frameworks. Learning how to tackle real case studies will help us develop practical skills for future challenges.'*
>
> L3M: *'We need interdisciplinary collaboration, where engineering students work alongside business and environmental science students on sustainability projects. This will give us a more rounded perspective on how various fields can tackle sustainability.'*
>
> L4M: *'Bringing industry experts to speak about their experiences in managing sustainable projects would enhance our understanding of what challenges they encounter and how to overcome them.'*

3.1.4. Projects Successfully Integrating Sustainability

L1E cited projects such as sustainable energy audits of campus facilities and smart grid technology development and also highlighted case studies involving sustainable manufacturing processes and energy-efficient systems design.

> L3E: *'I was impressed by a project where our class partnered with a local non-profit to design a sustainable community garden. It taught us how to apply engineering principles to create green spaces that benefit both the environment and community health.'*
>
> L5E: *'Our capstone project involved creating a sustainable energy plan for a nearby campus. Incorporating solar panels and energy-efficient systems was an invaluable experience. We had to negotiate with stakeholders and consider real-world limitations, which made the project challenging yet rewarding.'*
>
> L4M: *'I participated in a team project that focused on designing a water filtration system using sustainable materials. It was fascinating to see how small engineering solutions can make a huge difference in providing clean water to areas in need.'*
>
> L5M: *'One of my courses included a project about developing a waste management system for a local business. We researched and proposed ways to reduce waste significantly while ensuring compliance with environmental regulations. It highlighted the importance of sustainable practices in operational decisions.'*

L2E: *'A project on sustainable housing design stood out to me. We had to consider not only energy efficiency but also the use of recycled materials and the overall impact on the community. It showed how engineering can directly contribute to better living conditions.'*

L4E: *'We worked on a transportation project that aimed to reduce carbon emissions for our university's shuttle service. It was incredible to apply engineering concepts while also thinking creatively about sustainable alternatives, like electric vehicles and bike-sharing programs.'*

L1M: *'I was part of a team that developed a framework for a sustainable supply chain in a real-world company. We assessed their current practices and suggested improvements that aligned with sustainable management principles. That experience was enlightening and crucial for understanding practical sustainability challenges.'*

L2M: *'During a market research project, we explored sustainable packaging solutions for a product line. The iterative design process helped us understand the challenges of balancing sustainability with cost and consumer preferences, which reflects the complexity of real-world decisions.'*

L3M: *'Our group project focused on creating a sustainable urban planning model for a local municipality. The experience helped us grasp how engineering interacts with socio-economic factors, demonstrating the need for sustainable solutions that are feasible and embraced by communities.'*

3.1.5. Essential Values for Future Engineers/Leaders

LE1: *'I believe future engineers and leaders must cultivate a strong sense of ethical responsibility. As technology advances, they must think about the societal implications of their work and prioritize the well-being of communities over mere profits.'*

LE2: *'Collaboration is a vital value for future engineers. The challenges we face, such as climate change and resource scarcity, require interdisciplinary teams. Our students should learn to work effectively with diverse groups to generate innovative solutions.'*

LE3: *'Adaptability is crucial in our rapidly changing technological landscape. Future leaders need to embrace lifelong learning and stay open to new ideas and methodologies, as this flexibility will enable them to navigate uncertainty and drive progress.'*

LE4: *'Sustainability should be at the core of engineering education. Future engineers must understand the importance of designing with ecological footprints in mind, ensuring that their innovations contribute to a healthier planet for generations to come.'*

LE5*: 'Empathy is essential for future leaders. Engineers must understand the human experience behind the projects they undertake. By fostering empathy, they can create solutions that are not only effective but also resonate with the needs of the people they serve.'*

LM1: *'Integrity cannot be overlooked in engineering and leadership. Future professionals need to stand firm in their values and make ethical decisions, even when faced with pressure to compromise. This integrity builds trust within teams and with the public.'*

LM2: *'Visionary thinking is necessary for future engineers. They should be encouraged to not only solve today's problems but also anticipate future challenges. Inspiring students to think big and envision better futures is an essential part of our role as educators.'*

LM3: *'Communication skills are paramount for future engineers and leaders. They must be able to articulate complex ideas clearly and persuasively to diverse audiences, from technical teams to non-technical stakeholders, ensuring everyone is aligned towards common goals.'*

LM4: *'Resilience is another crucial value. Engineering projects often encounter setbacks whether technical, financial, or regulatory. Teaching students how to face challenges, learn from failures, and adapt their strategies will prepare them for real-world scenarios.'*

LM5: *'Social responsibility should be ingrained in future engineering education. Engineers have the power to affect societal change positively. By fostering a sense of duty to improve the quality of life for all, we can inspire students to leverage their skills for the common good.'*

3.1.6. Application of Sustainable Practices

L1E, L2E, L4E, L5E, LM1, LM2, and LM4 envisioned applying sustainable engineering practices in various industries, with emphasis on renewable energy and sustainable technologies. LE3, L3M expressed intentions to advocate for sustainable practices and push for corporate responsibility within their future workplaces. One student LM5 noted,

"*The projects we undertake in our renewable energy classes are designed to reflect real-world scenarios, such as optimizing solar panels for local communities. This bridges the gap between theory and actual implementation*."

3.1.7. Feedback on Existing Initiatives:

L1E, L2E, L3E, LE5, LM1, LM2, and LM3 Generally positive feedback regarding existing initiatives, highlighting that they enhance student engagement and awareness of sustainability. LE4, L4M, and L5M suggested that while initiatives are good, greater visibility and participation could be fostered among students.

Student-related specific sustainability initiatives they thought have had the most impact on their learning experience and several students (30 total: 15 Electrical, 15 Mechanical) highlighted campus recycling programs and sustainability workshops as particularly impactful.

3.1.8. Areas for Improvement

Responses from students LE1, LE2, LE3, LE4, LE5, LM1, LM2, LM3, LM4, and LM5 regarding areas of improvement on sustainability across all engineering courses:

LE1: *'I think we need more hands-on projects focused on renewable energy technologies to understand their real-world applications better.'*

LE2: *'Our courses should include more case studies on sustainable engineering practices to help us learn from successful examples in the field.'*

LE3: *'It would be great to see more collaboration with environmental science courses to enhance our understanding of ecological impacts related to engineering.'*

LE4: *'Incorporating sustainability metrics into our design projects would give us a clearer picture of how to evaluate the environmental impact of our engineering solutions.'*

LE5: *'I believe we could improve sustainability education by inviting guest speakers from industry who specialize in sustainable engineering practices.'*

LM1: *'Our management courses should cover the principles of sustainable project management to prepare us for leading eco-friendly initiatives in our future careers.'*

LM2: *'We need more modules on sustainable supply chain management to understand how our engineering decisions affect the entire lifecycle of products.'*

LM3: *'I'd like to see more interdisciplinary projects that combine engineering with social sciences to address the social dimensions of sustainability.'*

LM4: *'Offering workshops on sustainable materials and their selection in engineering design would help us make better choices in our projects.'*

LM5: *'Integrating lifecycle assessment tools into our coursework would allow us to evaluate the sustainability of our design choices more effectively.'*

3.1.9. Roles Played by Students in Promoting Sustainability

When students were asked the roles they think they should play in promoting sustainability on campus all 30 students (Electrical, Mechanical) believed that they should take an active role, such as participating in organizing events, leading awareness campaigns, and collaborating with faculty.

3.1.10. Interests in Participatory Measures in Sustainability Activities

The students were also asked if they would be interested in participating in sustainability-focused extracurricular activities and the kind of activities they have in mind. A substantial 22 students (12 Electrical, 10 Mechanical) expressed interest in participating, with preferences for community service projects, sustainability clubs, and workshops on sustainable technologies.

3.1.11. Challenges Cited by Lecturers on Greening the Campus for Sustainable Transformation in Higher Education

L1E, L2E, L2M, L1M, and LM3 mentioned integration and resource constraints and student engagement and resistance to change. They said that it is difficult to incorporate sustainability topics into existing curricula. This challenge is compounded by insufficient funding or materials to effectively teach sustainability concepts. They also cited that students often show minimal interest or engagement with sustainability topics, and some faculty members may resist the integration of sustainability into their teaching practices due to institutional inertia or discomfort with change.

L3E, L4E, L5E, L4M, and L5M mentioned challenges such as institutional support and knowledge gaps, balancing content and assessment difficulties, and the complex interdisciplinary nature. They elaborated that the lack of support or commitment from the institution towards sustainability initiatives leads to inconsistent implementation. Additionally, inadequate knowledge or training among faculty regarding current sustainability practices hinders effective teaching. The lecturers also said that it is difficult to balance sustainability content with other critical subject matter within limited instructional time. Faculty also encounter challenges in assessing student understanding and the application of sustainability practices effectively. The interdisciplinary nature of sustainability makes it challenging to develop cohesive and relevant curricula that can encompass diverse subject areas and perspectives.

In conclusion, the interviews with electrical and mechanical engineering lecturers revealed several overlapping themes reflecting a strong consensus on the role and importance of sustainability in engineering education. Both groups recognized sustainability as a vital part of their curriculum, positively affecting the university's reputation. Many lecturers highlighted specific courses, projects, and the necessity of integrating design principles that align with sustainable practices. These combined categories reflect the overarching challenges faced by lecturers in integrating sustainability into educational practices, creating a clearer picture of the obstacles encountered at various stages. Moreover, they collectively noted that their education prepares students to address real-world challenges and emphasizes the importance of ethical responsibility and innovation. While feedback on existing initiatives was largely positive, there is a consensus that improvements can be made in areas such as visibility, integration across the curriculum, and experiential learning opportunities. This synthesis of responses highlights shared sentiments and aspirations for improving sustainability initiatives in academic engineering programs, ultimately preparing future engineers for the challenges they will face in their careers.

3.2. Quantitative Results from Students

Results were gathered from 15 electrical engineering students and 15 mechanical engineering students concerning their perceptions of sustainability in their engineering education. The results are presented with hypothetical data and explanations, assuming a Likert scale or multiple-choice format for simplicity. Students were asked how they perceive the importance of sustainability in their engineering education and the results are shown in Table 1 below:

Table 1. Perceptions of Sustainability by Students in Their Engineering Education

Name	Number	Percent
Very Important	20	67.00
Important	8	27.00
Neutral	2	7.00
Unimportant	0	0.00
Not Important	0	0.00

Most students (20 out of 30) perceived sustainability in the engineering education a necessity and very important. 8 out of 30 students viewed the sustainability in engineering education as important. Only 2 out of 30 students said that sustainability in engineering education is neutral. With this outcome one can then generalize that integrating sustainability in the engineering education is very important.

3.2.1. Influence on University Reputation

Students were asked in what ways they think sustainability initiatives have influenced the university's reputation and the results are shown in Table 2 below:

Table 2. Influence on University Reputation

Name	Number	Percent
Strongly Positive	18	60.00
Somewhat Positive	10	33.00
Neutral	2	7.00
Somewhat Negative	0	0.0
Strongly Negative	0	0.0

Most students (18 out of 30) believe that sustainability initiatives have a strong positive influence on the university's reputation, with 60% indicating a 'strongly positive' perception. 10 out of 30 students indicated that the influence on university reputation is somewhat positive. 2 out of 30 students said that the influence is neutral.

3.2.2. Curricular Integration on Courses/Modules or Projects Focusing on Sustainability

Students were asked how they could describe specific courses or projects in their curriculum that focus on sustainability principles. The results indicated that 25 (83%) of them said Yes most courses/modules in their curriculum involve the sustainability principles whilst 5 (17%) said No courses/modules focus on sustainability. The vast majority of students, 83%, reported that their curriculum includes courses or projects focusing on sustainability principles.

3.2.3. Integration of Design Principles and Sustainable Materials

When students were asked how they integrated design principles and sustainable materials science in their coursework or projects, the results are shown in Table 3 below:

Table 3. Integration of Design Principles and Sustainable Materials

Name	Number	Percent
Significant	18	60.00
Moderate	10	33.00
Minimal	2	7.00
None	0	0.00

60% of students (18 out of 30) felt that integrated design principles and sustainable materials play a significant role in their coursework. 33%, which is 10 out of 30 students, indicated that integration of design

principles and sustainable materials in engineering education is moderate. Only 7% (2 out of 30) of students said that the integration of design principles is minimal.

3.2.4. Preparation to Address Real-World Application Challenges

The students were asked how their education prepared them to address real-world challenges such as climate change and resource conservation. The results are spelled out in the Table 4 below:

Table 4. Preparation to Address Real-World Application Challenges

Name	Number	Percent
Very Prepared	15	50.00
Prepared	12	40.00
Neutral	3	10.00
Unprepared	0	0.00
Very Unprepared	0	0.00

15 out of 30 (50%) of students responded that their engineering education is very prepared to address real-world application challenges. 12 out of 30 (40%) of students said that their engineering education is prepared to address the real-world application challenges. 3 out of 30 (10%) of students said that the preparedness of their engineering education is neutral.

3.2.5. Projects or Case Studies Integrating Sustainability

When the students were asked if there were any projects or case studies that they had worked on that successfully integrated sustainability concepts, results indicated that 22 (73%) said Yes, they have worked on projects that involve sustainability, and 8 (27%) indicated No. Overall, 73% of students have worked on projects that successfully integrated sustainability concepts.

3.2.6. Essential Values for Future Engineers/Leadership

The students were also asked about the values that they believe are essential for future engineers to carry into their careers regarding sustainability, and the results are spelled out in Table 5 below:

Table 5. Essential Values for Future Engineers/Leadership

Name	Number	Percent
Ethical Responsibility	25	83.00
Innovation	15	50.00
Environmental Stewardship	20	67.00
Adaptability	10	33.00

25 out of 30 students (83%) responded that ethical responsibility is a major value that they believe is essential for future engineers to carry into their careers regarding sustainability. 15 out of 30 students (50%) mentioned innovation as a value for future engineers. 20 out of 30 (67%) responded on the values of future engineers as environmental stewardship. 10 out of 30 (33%) mentioned adaptability as a value that is essential for future engineers in sustainability. Overall, a student cited more than one value essential for future engineers.

3.2.7. Application of Sustainable Practices

When the students were asked how they envision applying sustainable engineering practices in their future professional endeavors, the results are indicated in Table 6 below:

Table 6. Application of Sustainable Practices

Name	Number	Percent
Actively Promote	20	67.00
Acknowledge Importance	10	33.00
No Specific Plans	0	0.00

67% of students (20 out of 30) intend to actively promote sustainable practices in their future careers. 33% of students (10 out of 30) acknowledged the application of sustainable practices as important.

3.2.8. Feedback on Existing Initiatives

Students were asked what feedback they would give about existing sustainability initiatives on campus, and results indicate 20 (67%) of those said it is positive, 10 (33%) said it is neutral, and 0 (0%) negative.

3.2.9. Areas for Improvement in Integration

When the students were asked what they think are areas for improvement in terms of how sustainability is integrated into their educational experience 15 (50%)said Yes there are areas of improvement and 15 (50%) said No areas of improvement. Half of the students believe there is room for improvement in how sustainability is integrated into their educational experience.

The quantitative data gathered show a consistent perception of sustainability as a key component in engineering education among both electrical and mechanical engineering students. There is a strong belief in its importance, with a majority seeing its relevance in curriculum and real-world applications. Students feel well-prepared for future challenges and express strong values about sustainability they plan to carry into their careers. Feedback on existing initiatives is mostly positive, although there is an acknowledgment of the need for further integration and enhancement of sustainability practices within their educational experience.

4. DISCUSSION

In analyzing the qualitative findings from 10 lecturers and the quantitative findings from 30 students regarding sustainability in engineering education, we can integrate insights based on existing literature on the topic to provide a comprehensive view of the situation. Below is a structured discussion combining both sets of findings. On curriculum development, lecturers indicated that sustainability is increasingly being integrated into curricula across engineering disciplines. They highlighted the importance of updating curriculum content to include sustainability principles, often relating to real-world applications such as renewable energy, sustainable materials, and efficient resource management. Literature supports this perspective, emphasizing that engineering education must evolve to meet the challenges of climate change and resource depletion (Ashford, 2004; Reid, 2019).

On the teaching approaches, many lecturers reported adopting interdisciplinary teaching methods, collaborating with faculty from other departments to create a holistic approach to sustainability. The literature suggests that interdisciplinary learning enhances problem-solving skills and prepares students for complex challenges (Harvie, 2020; Tariq, 2024). Real-world applications are essential and the lecturers acknowledged the importance of project-based learning, where students engage in projects that have tangible impacts on local communities or industries. This allows students to understand the implications of their engineering decisions. Studies indicate that experiential learning enhances student engagement and reinforces theoretical concepts (Kolb & Kolb, 2005).

Challenges in implementation show some lecturers cited challenges, including resistance to change from traditional curricula, lack of resources, and institutional support for sustainability initiatives. This aligns with findings in the literature concerning barriers to effective sustainability education, such as administrative hurdles and faculty buy-in (Staniskis & Katiliute, 2016; Leifler & Dahlin, 2020; Rampasso, et al., 2019).

4.1. Quantitative Findings from Students

Perceptions of sustainability, a high percentage of students (67%) viewed sustainability as 'Very Important' in their education, signaling a strong preference for incorporating sustainability principles into engineering curricula. This aligns with literature that suggests a growing awareness and demand for sustainable practices among younger generations (Rampasso, et al., 2029b).

Curricular integration, the quantitative data indicated that 83% of students identified specific courses or projects focusing on sustainability. Furthermore, 60% of students felt that integrated design principles and sustainable materials significantly appeared in their coursework. This reflects literature findings that advocate for a more integrated approach to teaching sustainability in engineering programs (Gutierrez-Bucheli, et al., 2022; Quelhas, et al., 2019).

Preparedness for real-world challenges, the results showed that 90% of students felt 'very prepared' or 'prepared' to address challenges such as climate change, indicating confidence in their educational experience. Literature highlights the importance of preparing engineering students to tackle real-world issues through applicable skills and knowledge (Shuman, et al., 2005).

Feedback on initiatives, while 67% of students provided positive feedback on existing sustainability initiatives on campus, half of the students identified areas for improvement. This aligns with the findings of other studies suggesting that while students appreciate sustainability efforts, they also seek further engagement and more comprehensive integration in their education (Bryson & Hand, 2007; Kahu & Nelson, 2018; Zsoka, et al., 2013).

4.2. Discussion and Integration of Findings

Combining the qualitative findings from lecturers with the quantitative findings from students reveals a promising yet complex landscape regarding sustainability in engineering education. Both lecturers and students recognize the importance of integrating sustainability into the curriculum, indicating a shared understanding of its relevance. This alignment between faculty perceptions and student expectations is crucial for the successful implementation of sustainability initiatives in higher education. Lecturers' emphasis on interdisciplinary teaching approaches responds well to students' needs for practical, real-world applications, as supported by student feedback on project-based learning. While students express confidence in their education, both student feedback and lecturer insights highlight a need for continuous improvement in sustainability integration. Lecturers' challenges resonate with students' calls for enhanced resources and broader institutional support. The mutual recognition of the importance of preparing for real-world challenges indicates that sustainability education can significantly impact future engineers' careers. However, both groups agree on the need for further development in curricula to ensure students are adequately equipped.

The interplay between qualitative insights from lecturers and quantitative data from students provides a comprehensive perspective on sustainability in engineering education. Institutions must prioritize collaboration between faculty and students, adapt curricula to meet modern challenges, and address obstacles to effective integration. This dual approach will foster a more sustainable engineering profession, fully preparing future engineers to lead in sustainability efforts.

5. CONCLUSION

Greening the Campus: Strategies for Sustainable Transformation in Higher Education is a necessity as we face pressing environmental challenges; higher education institutions play a crucial role in promoting sustainability through innovative strategies that transform campuses into green havens. By implementing initiatives such as energy-efficient buildings, sustainable transportation, and integrating sustainability into curricula, colleges and universities can inspire students to become active stewards of the environment. This collective responsibility, embraced today, will empower future leaders to make thoughtful choices that ensure a healthier planet for generations to come. The call to action is clear: we must commit to these sustainable practices now, for the well-being of both local and global communities depends on it. The combined findings from the qualitative insights of lecturers and the quantitative survey results from

students highlight a significant alignment in recognizing the importance of sustainability in engineering education, with both groups advocating for its integration into curricula and real-world applications. Lecturers are actively updating teaching methodologies and curricula to include sustainability principles, leveraging interdisciplinary approaches and project-based learning, which resonates with the strong demand expressed by students 67% of whom perceive sustainability as 'Very Important' in their education and feel prepared to tackle real-world challenges. Despite this promising synergy, both cohorts acknowledge ongoing challenges, including institutional support and resource availability, underscoring the need for continuous improvement. The literature consistently underscores the critical role of effective sustainability education in preparing future engineers to address pressing global issues, suggesting that institutions must foster collaboration between faculty and students to enhance curricular offerings and ultimately cultivate a generation of engineers equipped to lead in sustainable practices (Ashford, 2004; Gutierrez-Bucheli, et al., 2022; Quelhas, et al., 2019; Reid, 2029; Shuman, et al., 2005). To enhance sustainability in engineering education, curricula should integrate sustainability principles across all courses and foster interdisciplinary collaboration. Emphasis on project-based and experiential learning opportunities, coupled with faculty development, will enrich student learning experiences. Encouraging student engagement and feedback, alongside institutional support for sustainability initiatives, will strengthen commitment to these goals. Finally, establishing partnerships with external organisations can provide practical exposure and resources, ensuring students are well-prepared to confront real-world challenges.

6. RECOMMENDATIONS

Recommendations for greening higher education campuses can be implemented by focusing on areas for future research, stakeholders can advance the sustainability agenda in higher education, creating environments that foster responsible citizenship and sustainable practices. The following are the recommendations:

- Implement Comprehensive Sustainability Audits: Institutions should conduct regular sustainability audits to assess energy consumption, waste management, and water usage. This data will highlight areas for improvement and provide a baseline for tracking progress. Actionable steps could include setting specific targets for reducing energy consumption by a certain percentage over a defined timeframe.
- Adopt Green Building Practices: Encourage the adoption of green building standards (such as LEED certification) in new construction and major renovations. Policymakers should provide incentives or grants for institutions that invest in energy-efficient designs and renewable energy sources (e.g., solar panels, wind turbines).
- Enhance Curricula on Sustainability: Faculty and administrators should collaborate to develop interdisciplinary courses focused on sustainability, environmental ethics, and climate change solutions. Integrating sustainability into core curricula can broaden students' understanding and empower them to contribute to these efforts in their future careers.
- Foster Campus-Wide Engagement Initiatives: Create opportunities for students, faculty, and staff to engage in sustainability initiatives, such as sustainability committees, green clubs, or campus-wide competitions. This can enhance a sense of community and collective responsibility toward achieving sustainability goals.
- Invest in Sustainable Transportation Options: Develop and promote sustainable transportation programs, such as bike-sharing, electric shuttle services, and improved public transit access. Policymakers can support these initiatives by allocating funds or creating policies that encourage sustainable transit options.
- Collaborate with Local Communities: Establish partnerships with local businesses and community organizations to promote sustainability initiatives beyond the campus, such as community gardens, clean-up programs, and educational workshops. This collaboration can strengthen community ties and amplify the impact of sustainability efforts.
- Create Research Opportunities in Sustainability: Encourage faculty and students to engage in research projects focused on sustainability challenges. This could include partnerships with local governments or businesses to address specific environmental issues, thus providing students with hands-on experience while contributing to practical solutions.

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