An Evaluation of Sustainability Knowledge and Practices of Undergraduate Engineering Programs

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Abstract
High-quality education is required for a sustainable society, particularly in the engineering profession, where future global leaders play a critical role. To accomplish this, sustainability must be integrated into Higher Education Institutions (HEIs). As people's concerns about the environment's impact on them grow, so does the importance of sustainable development. It is critical to assess students' knowledge and efforts in engineering courses in order to communicate an institution's strategic direction. The purpose of this research is to better identify the level of sustainability implemented by students, who constitute a sizable number of HEI stakeholders. The research was conducted in a HEI in Manila, Philippines, using a mixed methodological approach with a sequential explanatory design. A survey was created to collect and analyze quantitative data, which was then supplemented with qualitative insights from a focus group discussion. The study's findings show how HEIs may improve sustainability by understanding the dynamics of change and acting as change agents. We can develop a more sustainable and responsible engineering profession by including sustainability into education, ultimately contributing to a more sustainable global future.

Keywords
Sustainability, Engineering, Higher Education Institutions (HEI), Sustainable Development Goals (SDG)

1. Introduction
A sustainable world requires high-quality education that incorporates sustainability principles, especially in the engineering profession, where future global leaders play a critical role (Žalėnienė & Pereira, 2021). Higher Education Institutions (HEIs) are responsible for shaping undergraduate engineering programs and preparing students to apply sustainable practices (Leal Filho et al., 2019). With growing worries about the influence of the environment on persons and organizations, sustainable development has grown in importance around the world (Mensah, 2019). In order to encourage responsible and sustainable engineering practices, it is critical to include sustainability into engineering education (Miñano Rubio et al., 2019).

To effectively address the difficulties of sustainability in the engineering profession, it is critical to analyze undergraduate engineering students' present level of sustainability knowledge and practices (Beagon et al., 2022). HEIs can integrate their educational methods and curricula with sustainable development goals by understanding students' perspectives and evaluating their sustainability efforts (Ferrer-Estévez & Chalmeta, 2021). This evaluation will be used to promote sustainability integration in undergraduate engineering programs and to shape future engineering professionals.

1.1 Objectives
The primary goal of this research is to assess undergraduate engineering programs' sustainability knowledge and practices at a Higher Education Institution (HEI) in Manila, Philippines. The study's specific goals are as follows:

- Determine undergraduate engineering students' level of sustainability knowledge and understanding.
- Evaluate how well sustainability principles are integrated into engineering courses and projects.
- Identify the obstacles and challenges that students experience when implementing sustainability practices.
- Investigate potential sustainability techniques and efforts in undergraduate engineering programs.

1.2 Significance of the Study

The findings of this study will add to the body of information on sustainability education in undergraduate engineering programs. HEIs can design targeted interventions and strategies to improve sustainable integration by evaluating students' sustainability knowledge and activities (Alm et al., 2022). Furthermore, the study will shed light on the constraints and obstacles that students have when seeking to integrate sustainability principles, providing valuable insights for curriculum development and pedagogical techniques.

2. Sustainability Education in Higher Education Institutions

Due to the growing importance of sustainable development, sustainability education has received substantial attention at Higher Education Institutions (HEIs) globally. To tackle the difficulties of a sustainable environment, HEIs must integrate sustainability into their programs (Findler et al., 2019).

Engineering professionals have a tremendous impact on society and the environment through the projects they develop and implement. As a result, it is critical for engineering students to gain a thorough understanding of sustainability principles and their application in engineering practice. Sustainability education provides students with the knowledge, skills, and values needed to design sustainable solutions, reduce environmental effect, and satisfy social demands (Gutierrez-Bucheli et al., 2022). By incorporating sustainability into engineering education, HEIs may better prepare future engineers to contribute to a more sustainable global future.

2.1 Level of Sustainability Awareness and Understanding among Engineering Students in the Philippines

Sustainability education in the Philippines has grown in popularity in recent years, owing to a growing awareness of the country's environmental concerns and the need for long-term development. The incorporation of sustainability principles into engineering education is critical for preparing future engineers to effectively solve these difficulties (Valencia, 2018). To encourage sustainability education among engineering students, many projects and programs have been developed at Philippine higher education institutions.

Previous research studies in the Philippines investigated the level of sustainability awareness and understanding among engineering students. These studies collected data on students' knowledge, attitudes, and perceptions of sustainability ideas through surveys, questionnaires, and interviews. These studies' findings provide insights into the current level of sustainability education and highlight opportunities for development.

In particular, Debrah et al. (2021) examined the sustainability literacy of students in developing countries institutions. The findings demonstrated that, while students had a basic awareness of sustainability concepts, there was a need for additional instruction and the incorporation of sustainability principles into the curriculum. It was discovered that while students had positive attitudes toward sustainability, their knowledge of specific sustainability principles was poor.

2.2 Integration of Sustainability Principles into Engineering Courses and Projects

HEIs in the Philippines have taken a variety of approaches to incorporating sustainability principles into engineering courses and projects. Curriculum development and modification, pedagogical tactics, multidisciplinary collaboration, and partnerships with industry and community stakeholders are all examples of these approaches. Curriculum creation and revision entail adding sustainability-related themes and concepts into existing engineering courses or developing specialized courses focusing on sustainable engineering (Ashraf & Alanezi, 2020). This guarantees that students have a thorough understanding of sustainability principles and their implementation in engineering practice.

Integrating sustainability into higher education institutions has various advantages. For starters, it raises students' knowledge and understanding of sustainability issues, allowing them to make informed decisions and meaningfully contribute to sustainable development (Fuertes-Camacho et al., 2019). Second, because it necessitates the integration of social, environmental, and economic viewpoints, sustainability education fosters interdisciplinary collaboration (Liu et al., 2022). This multidisciplinary approach encourages pupils to think holistically and solve problems. Third, by creating graduates who are well-versed in sustainability principles and can contribute to sustainable innovation and practices, sustainability education can strengthen the interaction between HEIs and the industry (Obrecht et al., 2022). Finally, HEIs that incorporate sustainability into their strategic orientation and educational offerings improve their reputation and attract students who are interested in programs that are focused on sustainability.

3. Methods

A mixed-method technique, specifically a sequential explanatory design, was used in this investigation. This design comprises collecting and analyzing quantitative data through a survey, followed by collecting and analyzing qualitative data through focus group discussions. Undergraduate engineering students can obtain a thorough understanding of sustainability principles and practices thanks to the sequential explanatory design.
This study's target participant are engineering students from a certain university in Manila, with a total population of N=3,413. The survey and focus groups were part of the data collection procedure.

A survey questionnaire was created to measure engineering students' sustainability knowledge, opinions, and practices. Multiple-choice questions, Likert-scale evaluations, and free-text replies were included in the survey. The university's Data Privacy Office reviewed the survey, and the link to the survey was delivered to the target respondents via their official university email and e-learning platform, using the web software "Typeform."
Focus group discussions were used to gain qualitative insights and in-depth perspectives on sustainability knowledge and practices. Due to the continuing COVID-19 outbreak, the focus groups were held online via the Zoom platform. Focus Group Discussion (FGD) moderators were guidance counselors from the guidance counseling department, with a technical assistant on hand to assist with any technical concerns. A mock FGD was held to test the validity of the questions and provide direction to the moderators and technical assistants. The actual FGDs were held on the same day, using Zoom breakout rooms, and recordings were made for analysis.

3.1 Data Analysis

The survey's quantitative data were examined using acceptable statistical procedures. To summarize the survey responses and detect trends and patterns in sustainability knowledge and practices among engineering students, descriptive statistics such as frequencies, percentages, and averages were produced.
Thematic analysis was used to assess the qualitative data gathered from the focus group conversations. The data from the recorded discussions was methodically coded and grouped into themes and sub-themes. Identifying reoccurring patterns, ideas, and points of view connected to sustainability knowledge and practices among engineering students was part of this process.

Ethical considerations were taken into account throughout the research process. All participants gave their informed consent, ensuring their voluntary participation and the confidentiality of their comments. The study followed ethical norms for human-participant research, and precautions were taken to protect the participants' privacy and identity.
Certain limitations of this investigation should be acknowledged. The study was carried out at a single university, which may limit the findings' applicability to other engineering programs or institutions. Although efforts were made to enhance participation by reminders and discussion with program chairmen, the 25% response rate in the target survey respondents may introduce sample bias. Furthermore, the current COVID-19 epidemic mandated online data gathering, which may have impacted the dynamics of the focus group conversations.

Table 1. Number of Survey Respondents from Different Engineering Degree Programs

Category	1st Year	2nd Year	3rd Year	4th Year	All Engineering Students (N = 846)
Bachelor of Science in Chemical Engineering	13	12	80	70	175
Bachelor of Science in Civil Engineering	24	18	106	49	197
Bachelor of Science in Computer Engineering	8	11	43	45	107
Bachelor of Science in Electrical Engineering	3	22	1	9	35
Bachelor of Science in Electronics Engineering	5	3	4	20	32
Bachelor of Science in Industrial Engineering	36	6	34	44	120
Bachelor of Science in Mechanical Engineering	7	8	76	46	137
Bachelor of Science in Mining Engineering	1	1		3	5
Bachelor of Science in Petroleum Engineering	2	9	19	8	38

4. Results and Discussion

4.1 Quantitative Results

In this section, researchers present and discuss the outcomes of the survey on the thoughts and opinions of university students on a variety of global and university-related problems. The information was gathered via a comprehensive questionnaire designed to learn about the students' problems, issues, and choices about sustainability, education, and their vision for a better society.

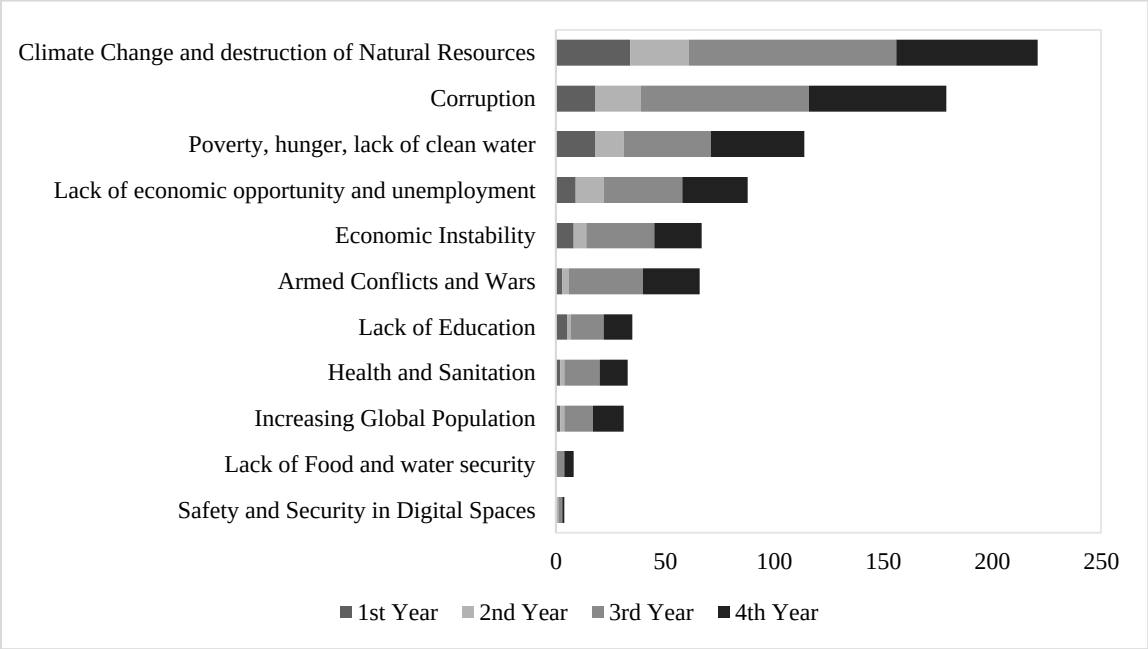

Figure 1. Response to "Which of the following do you consider the single most serious problem facing the world today?"

The distribution of responses to the question concerning the most severe global challenge facing the world today is depicted in Figure 1. The participants were given several options, and their choices are shown in the form of a bar chart. The graph illustrates the most prevalent concerns among students, giving light on the topics that are most pressing in their minds, with "Climate Change and destruction of Natural Resources" ranking first across all student year levels.

Table 2 provides a full overview of the participants' self-assessment of the ease or difficulty of doing various sustainability-related tasks. The responses were gathered on a scale of 1 to 10, with 1 representing great difficulty and 10 representing extreme ease. The table helps us identify the difficulties students face and identifies areas that require more assistance or interventions. Most Ease is "Reduce energy use (use natural lighting, turn off lights when leaving a room, turn off electronics when not in use)" and most Difficulty is "Make dietary choices for sustainability reasons (choose organic food, buy Fair Trade, eat less meat, or follow a plant-based diet)."

Table 2. Response to “To what extent do you believe it is difficult or easy for you to do the following.

Category	1st Year	2nd Year	3rd Year	4th Year	All Engineering Students
Reduce energy use (use natural lighting, turn off lights when leaving a room, turn off electronics when not in use).	8.02	8.27	8.16	8.33	8.20
Conserve water (minimize water use while washing dishes/hands or brushing teeth, take shorter showers).	7.42	7.59	7.94	7.88	7.58
Act to reduce waste (carry a reusable shopping bag, decline single-use bags/utensils/straws, take a reusable to-go container).	7.61	7.67	7.66	7.69	7.57
Choose sustainable transportation (carpool, walk, ride a bike, take public transit).	7.45	7.28	7.28	7.14	7.38
Talk with your friends or colleagues about problems related to the environment.	7.22	7.09	7.27	7.30	7.19
Make dietary choices for sustainability reasons (choose organic food, buy Fair Trade, eat less meat or follow a plant-based diet).	5.93	5.88	5.77	5.73	5.64
Engage in an activity because of its sustainability-related focus (take a course, create a course, attend a training or event).	6.58	6.67	6.74	6.91	6.53
Conserve paper (take fewer paper towels, print less often, use recycled paper, print double-sided, use digital documentation).	7.30	7.92	7.30	7.68	7.39
Avoid purchasing bottled water by consuming water from bulk sources, a refillable bottle, or the tap.	7.48	7.37	7.48	7.60	7.37
Carefully sort waste into appropriate recycle and compost bins, rather than dumping all waste together into one bin.	7.56	7.62	7.60	7.53	7.53

In Table 3, the researchers analyze the students' perceptions of their university. On a scale of 1 to 10, participants were asked to score their level of agreement with various propositions. The responses are divided into three categories, as shown in the table: strongly to moderately agree (7-10), neither agree nor disagree (4-6), and strongly to somewhat disagree (1-3). This analysis aids in determining the university's overall satisfaction and areas for development. Students firmly believe that the institution is "incorporating sustainability into research" and "incorporating sustainability into student organization activities" as a result of the results. However, "Providing options for sustainable travel" and "Saving electricity" are two areas that may need to be improved.

Table 3: Response to "I believe that our university is...."

Category	1st Year	2nd Year	3rd Year	4th Year	All Engineering Students
Using water efficiently	7.52	7.66	7.78	7.66	7.69
Protecting biodiversity on campus	7.86	8.34	8.14	7.95	8.07
Managing waste efficiently	8.03	8.47	8.35	8.14	8.25
Providing options for sustainable travel	7.49	7.53	7.20	6.93	7.17
Saving electricity	7.79	7.91	7.47	7.47	7.56
Adhering to environmental building standards	8.02	8.16	8.11	8.11	8.11
Including sustainability into teaching	8.01	8.14	8.00	8.05	8.04
Encouraging students to live sustainably	8.13	8.19	7.94	7.97	8.00
Including sustainability into research	8.27	8.59	8.32	8.50	8.41
Including sustainability in student organization activities	8.19	8.41	8.30	8.39	8.33

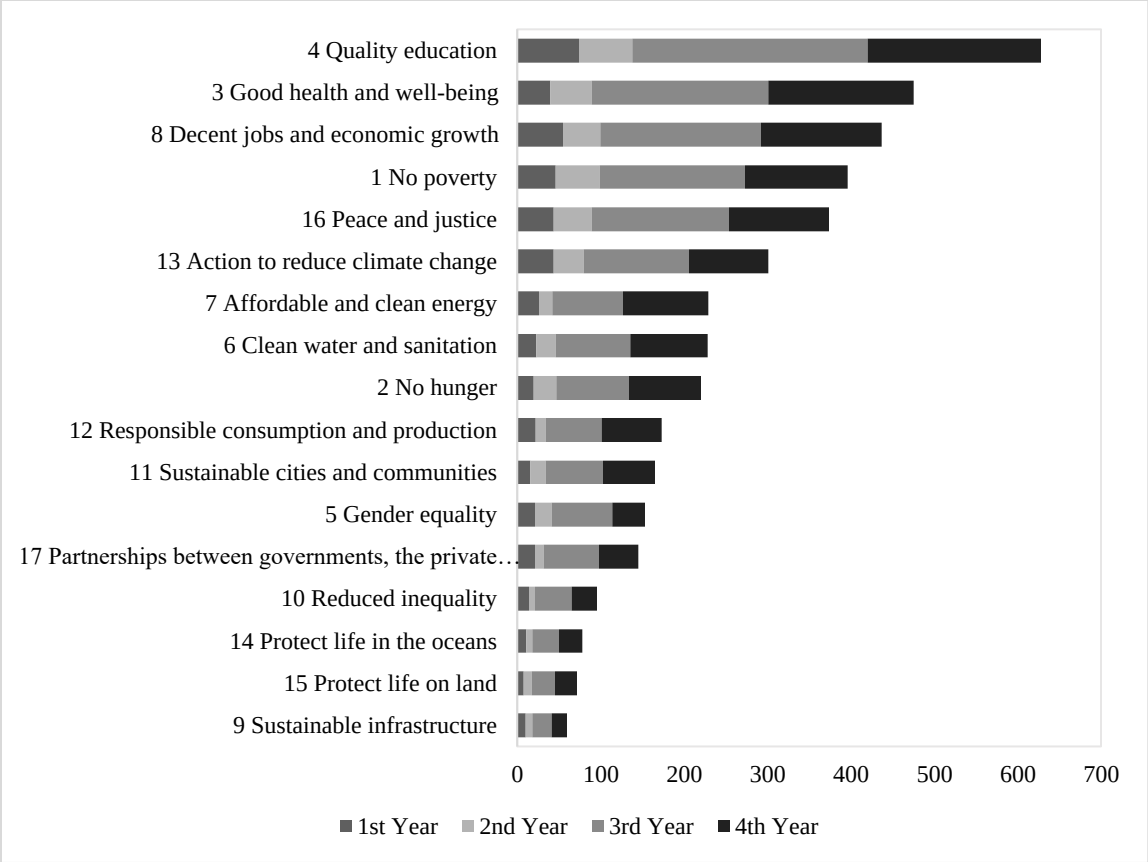

Figure 2. Response to "Select the Top Five (5) SDGs that are most important to you"

Figure 2 depicts the students' thoughts on the most important Sustainable Development Goals (SDGs). The graph highlights the top SDGs picked by respondents, providing vital insights into the areas they believe require immediate attention and action, which are SDG 4 - Quality Education, SDG 3 - Good Health and Well-being, and SDG 8 - Decent Jobs and Economic Growth.

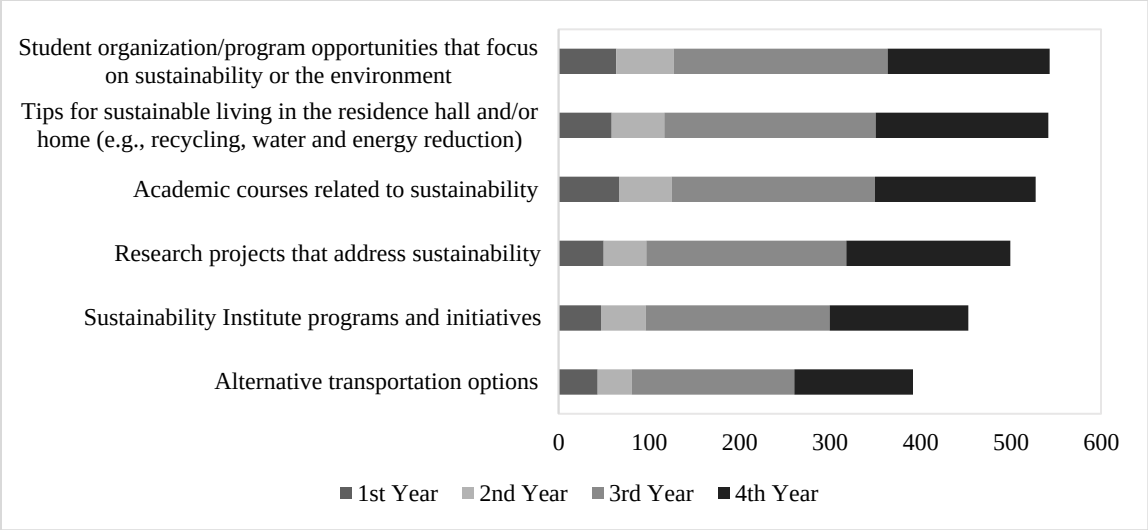

Figure 3. Response to "Which of the following would you wish to learn more about during your time at the university? Please check all the boxes that apply."

Figure 3 portrays the participants' interests in learning more about specific topics during their tenure at the university. The figure displays the percentage of students interested in each category, helping identify the subjects that resonate most with the student body such as "Student organization/program opportunities that focus on sustainability or the environment" and providing "Tips for sustainable living".

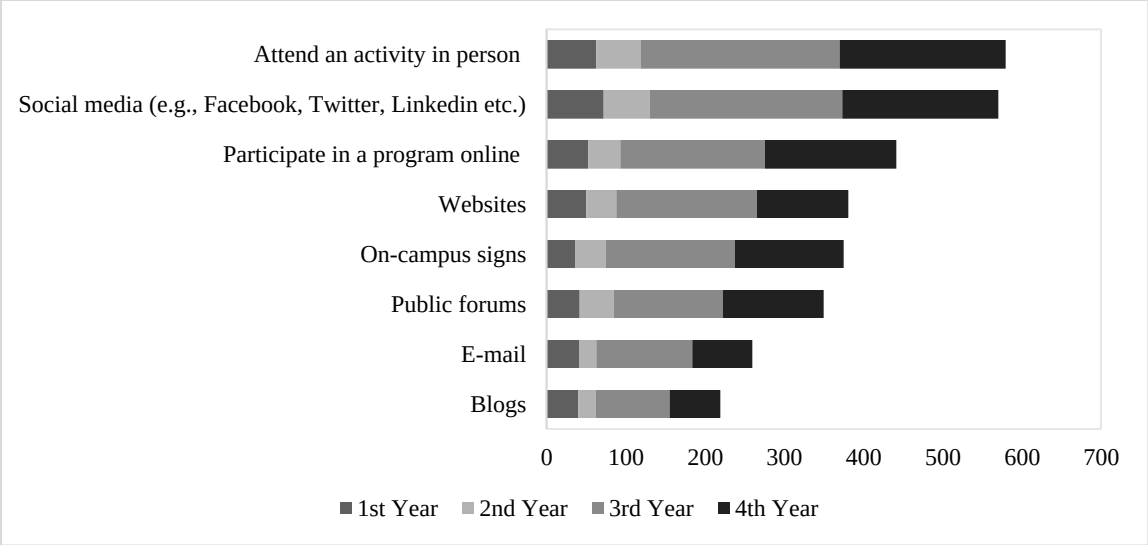

Figure 4. Response to "Which resource(s) would you consider the most useful for learning more about sustainability? Please check all of the boxes that apply."

Figure 4 depicts the numerous resources that students find most useful for broadening their understanding of sustainability. Respondents were requested to check all relevant options. The graph depicts the popularity of each resource, allowing us to identify that the most successful method of disseminating information and promoting sustainable practices are through "attending an activity in person" and via "social media".

The survey results provide valuable insight into the attitudes and preferences of university students. The findings reveal their key global concerns, the obstacles they experience in practicing sustainability, their assessment of the academic environment, and their interests in learning about various topics.
The statistics show that there is a considerable interest in sustainability-related topics among the student population, as well as a readiness to participate in acts that contribute to a more sustainable environment. It also emphasizes the significance of linking university programs and projects with the Sustainable Development Goals in order to effectively address students' concerns.

Furthermore, the survey results highlight the importance of the university providing resources and support for students' sustainability activities. Implementing educational programs that appeal to students' interests and preferred learning resources is part of this.

4.2 Qualitative Results

In this chapter, the researchers provide and discuss the findings of focus group discussions (FGDs) held to acquire a better understanding of participants' motives and expectations surrounding sustainability events or activities. The focus groups enabled this study to investigate the underlying motivations that motivate individuals to participate in sustainability activities, as well as the expected outcomes from such participation.

Question 1: What will motivate you to participate in a sustainability event or activity? Why?

The responses of the participants were divided into different themes, which are as follows:

- Advocacy and Relationship Building: Participants stated that participating in sustainability events or activities allows them to advocate for important causes and establish relationships with like-minded individuals. They can help to raise awareness and create positive change in their communities by actively participating.
- Support Sustainability and Help/Encouragement: Many participants stated that they are inspired to engage in sustainability events or activities because they believe in the necessity of supporting sustainable practices. They

also emphasized the value of assistance and support from peers, mentors, or sustainability advocates in inspiring their active participation.

- Taking Action and Responsibility: Participants stressed the importance of taking concrete efforts to solve sustainability concerns. They were motivated to participate in events or activities that allow them to make a difference and accept responsibility for their impact on the environment and society.
- Setting an Example and Demonstrating Commitment: Participants stated that participating in sustainability events or activities allows them to set an example for others and display their commitment to sustainable practices. They feel that by actively participating, they might inspire others to follow suit and contribute to a communal effort for a more sustainable future.
- Sense of Fulfillment: Participants stated that participation in sustainability events or activities provides them a sense of fulfillment and personal happiness. They feel fulfillment in knowing that their efforts have a beneficial impact and make a significant difference in the world.

Question 2: If you will be participating in a sustainability activity, what are your expectations or expected outcomes?

The responses of the participants were divided into different themes, which are as follows:

- Knowledge and Enlightenment: Participants expressed a desire to learn more knowledge and a deeper understanding of sustainability challenges by participation in activities. They believe that participating in such activities will extend their horizons and raise their understanding of environmental and social issues.
- Self-development: Participants stated that their participation in sustainability initiatives is motivated by a desire for personal growth and development. They hope to improve their skills in areas such as leadership, teamwork, problem solving, and critical thinking through hands-on experiences and interactions with others.
- A Broader View: Participants hope that taking part in sustainability activities will give them a broader perspective on global concerns and allow them to recognize the interdependence of environmental, social, and economic factors. They hope to get a more comprehensive grasp of sustainability and its use in different circumstances.
- Interactions and Actions: During sustainability activities, participants stressed the necessity of actively engaging with people and participating in collaborative initiatives. They anticipate interacting with people from a variety of backgrounds and working collaboratively to discover new solutions to environmental concerns.
- Encouragement and Advocacy: Participants expressed their hope that their involvement in sustainability activities will inspire others to get involved and generate a ripple effect in their communities. They also see it as an opportunity to advocate for sustainability and motivate others to become involved.

Overall, the FGD findings illustrate individuals' diverse reasons and expectations for participating in sustainability events or activities. The findings provide useful insights into the characteristics that generate engagement and the desired outcomes sought by participants. This understanding can be used to inform the design and implementation of future sustainability programs, ensuring that they align with the needs and ambitions of individuals and optimize their impact in fostering a more sustainable future.

5. Conclusion and Recommendation

The purpose of this study was to assess the level of sustainability knowledge and practices among undergraduate engineering students and to suggest opportunities for development within engineering schools. The research objectives were to determine students' sustainability knowledge, evaluate the integration of sustainability principles into engineering courses and projects, identify obstacles and challenges faced by students in implementing sustainability practices, and investigate potential sustainability techniques in undergraduate engineering programs.

Several key insights emerged based on the data and outcomes obtained:

1. Global Challenges and Sustainability: Response analysis found that "Climate Change and Natural Resource Depletion" was the most common concern among students across the entire college level This emphasizes the importance of including environmental concerns into engineering education.
2. Self-Assessment of Sustainability Tasks: According to the self-assessment data in Table 2, students considered minimizing energy consumption as the easiest sustainability-related task, while making food choices for sustainability

reasons as the most difficult. These findings point to the need for focused support and interventions to help students make sustainable food choices.
3. Perceptions of the institution: According to the examination of students' opinions in Table 3, the institution was perceived positively in terms of incorporating sustainability into research and student organization activities. However, topics such as offering sustainable transportation options and preserving electricity were noted as possible areas for improvement.
4. Importance of Sustainable Development Goals (SDGs): Figure 2 shows that students ranked SDG 4 (Quality Education), SDG 3 (Good Health and Well-being), and SDG 8 (Decent Jobs and Economic Growth) as the most important SDGs. This data can help influence curriculum development and link engineering programs with the SDGs that students care about.
5. Student Interests and chosen Learning Resources: Students' interests in certain sustainability themes (Figure 3) provide useful insights into the topics that are most appealing to them. Furthermore, students believe that attending in-person activities and using social media are the most effective resources for learning about sustainability (Figure 4). These findings highlight the necessity of providing different learning opportunities and employing digital platforms to communicate and promote sustainable practices.

The findings of the Focus Group Discussions (FGDs) revealed additional reasons and expectations among students for participating in sustainability events or activities. Advocacy and relationship building, support for sustainability, taking action and responsibility, setting an example, and a sense of fulfillment were among the themes that arose. Students expected information and enlightenment, self-development, a broader perspective, interactions and acts, and support and advocacy.

The following recommendations are made in light of these findings:

1. Improve Sustainability Education: Engineering programs should integrate sustainability principles throughout their curriculum, incorporating concepts and real-world applications into courses, projects, and research activities.
2. Improve Infrastructure and Practices: Universities should prioritize the improvement of sustainability-related infrastructure and practices, such as offering sustainable transportation options, optimizing energy usage, and implementing environmentally friendly policies.
3. Encourage Collaboration and Advocacy: Institutions should foster collaboration among students, professors, and external stakeholders to promote sustainability-focused programs, allowing students to advocate for sustainability and effect positive change in their communities.
4. Expand Co-curricular Activities: Provide a variety of co-curricular activities, such as student clubs and programs, that focus on sustainability, allowing students to participate actively and get practical experience in adopting sustainable practices.
5. Encourage Digital Engagement: Use digital platforms and social media to disseminate information on sustainability, boost student engagement, and encourage participation in sustainability events and activities.
6. Professional Development for Faculty: Provide faculty members with training and resources to improve their knowledge and comprehension of sustainability concepts, allowing them to effectively integrate sustainability principles into their teaching and research.

By applying these recommendations, undergraduate engineering schools may develop a sustainable culture, enable students to become responsible practitioners, and contribute to a more sustainable future.

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Biographies

Sheila Mae Carungay is a dedicated Full-Time Faculty Member in the Department of Industrial Engineering at Adamson University in Manila, Philippines. She has a B.S. in Industrial Engineering from Mapua University, as well as an M.S. in Management Engineering from Adamson University. Sheila has over 15 years of industry experience as a Professional Industrial Engineer. She has polished her skills in Supply Chain and Operations Management via her experience in a variety of industries, including semiconductor manufacture, hosiery manufacturing, food restaurants, and health and beauty retail. Sheila's dedication to the field extends beyond her work as a professor. She is an active member of the Philippine Institute of Industrial Engineers (PIIE), a prestigious organization that promotes collaboration and professional progress among Philippine industrial engineers. She helps and guides students in their academic and professional goals as the Faculty Adviser for the PIIE-ORSP Adamson Chapter. Sheila takes on the task of coaching students in their research and capstone projects as an advocate for undergraduate research. Her work as a class adviser ensures that students receive the help and support they require to succeed academically. Sheila's contributions to industrial engineering go beyond the classroom. She has presented and published research papers on the interface of Supply Chain and Sustainability both locally and internationally. Her work displays her dedication to improving knowledge and encouraging environmentally friendly methods in the industry. Sheila Mae Carungay, with her breadth of experience and passion to teaching, plays a critical role in molding the future of industrial engineering education.

Lourdes Lasian is a distinguished Industrial Engineering Professor at Adamson University in Manila, Philippines. She earned a Bachelor of Science degree in Industrial Engineering from the University of Sto Tomas and a Master of Business Administration from San Sebastian College-Recoletos Manila. Engr Lasian has an incredible 21 years of combined work experience in both the Manufacturing and Service Industries to her teaching capacity. She has been crucial in providing valuable insights to her pupils in a variety of courses, including management, feasibility, and other professional areas. Engr Lasian is a productive researcher in addition to her commitment to teaching. Her commitment to knowledge advancement is demonstrated by the production and presentation of research papers on both local and international venues. Her work demonstrates her interest in discovering new solutions and contributing to the field of industrial engineering. Notably, the academic community has recognized Lourdes Lasian's leadership talents. She was

the Chairperson of Adamson University, where she helped the institution expand and thrive. Engr Lasian, undeterred in her pursuit of academic greatness, is currently completing her PhD at UCSI Malaysia. Her drive to lifelong learning and intellectual curiosity indicate her desire to remaining at the forefront of the discipline and encouraging the next generation of industrial engineers.