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# Students and Alumni Perceptions of Sustainability in Engineering Education

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## ABSTRACT

### CONTEXT

Education for sustainable development (ESD) is critical for the improvement of sustainable development goals among engineering graduates. In order to produce engineers capable of creating resource-efficient technologies while taking into account the environmental and social implications, it is imperative that engineering education incorporates sustainable development (SD) concepts. The promotion of knowledge, innovation, and management philosophies are facilitated by investing in ESD within higher education institutions (HEIs), in order to advance research related to Sustainable Development Goals (SDGs) adopted by the United Nations for its Agenda for Sustainable Development by 2030.

### PURPOSE OR GOAL

To evaluate pedagogical contents and approaches to embed sustainable development (SD) into engineering undergraduates at Southeast Asia universities especially in specific institutions in Malaysia (due to limited data collection).

### APPROACH

This project employed both quantitative (online questionnaire) and qualitative (written interview) approaches, and the data were collected simultaneously. There are two phases in this study: Phase 1 represents the literature review on ESD in Southeast Asia, while Phase 2 is based on survey on engineering undergraduates at selected private universities in Malaysia and their respective alumni. This study uses a similar bottom-up approach that starts from student and alumni perspectives to raise undergraduates awareness of SD through survey questions.

### ACTUAL OUTCOMES

There is an increasing concern regarding sustainability in engineering design and development operations in different branches. This research will evaluate the learning outcomes to integrating SD into engineering education in Southeast Asia universities and will highlight strategies to enhance education for SD from countries that had successfully implemented it earlier.

### CONCLUSIONS

Both student and alumni responses underscore the importance of sustainability in engineering education and practice. Students exhibit growing competency with higher education levels, but gaps persist, particularly in environmental and social sustainability. To address these gaps, integrating sustainability tools and active learning approaches is essential to align graduate competence with workplace demands.

**KEYWORDS** Education for sustainable development (ESD), Engineering Education, Sustainable Competencies.

# 1 Introduction

Education for sustainable development (ESD) aims to help students integrate sustainability knowledge into decision-making, benefiting present and future generations (Seatter & Ceulemans, 2017). Engineers in Southeast Asia respond to the high demand for energy by reducing fossil fuel consumption through innovative practices (Pratiwi & Juerges, 2020; Ávila et al., 2017). Integrating SD into engineering education is crucial to produce engineers capable of designing sustainable technology with efficient resource use and understanding environmental and social impacts (Arefin et al., 2021). Investment in ESD at higher education institutions also contributes to research on SDGs, fostering knowledge and innovation among students (Žalėnienė and Pereira, 2021).

The concept of sustainable development (SD) emerged in 1992 during the United Nations Conference on Environment and Development (Mensah, 2019). The United Nations progressively introduced sustainability principles, focusing on the triple bottom line (TBL) aspects: economic, social, and environmental. This included initiatives like the Millennium Development Goals (MDGs) in 2000, aiming to reduce poverty, hunger, disease, environmental degradation, and discrimination against women. Sustainable Development Goals (SDGs) were developed in 2015, known as the successor to MDGs. SDGs have more agenda to work on than MDGs and are used to address global challenges, including poverty and hunger, inequality, climate change, environment.

In the direction of further advancement in global sustainable development, the World Summit on Sustainable Development (WSSD) was held in 2002 to review progress and create plans based on Agenda 21. Subsequently, in 2005, the UN established the Decade of Education for Sustainable Development (DESD) to promote sustainability in education and inculcated its principles in students (Liimatainen, 2013).

Education for Sustainable Development (ESD) is crucial as it enables engineers to create sustainable designs that benefit society, address environmental challenges, and are feasible for businesses. Engineering education needs to adapt with emerging trends as well by introducing complex systems and interdisciplinarity to enhance the curriculum (Hadgraft & Kolmos, 2020). This study explores barriers to integrating SD into engineering education in Southeast Asia, especially in some institutions in Malaysia and compares practices with other countries like the USA, China, and UK to enhance SD integration. It assesses students' SD skills through surveys and also gathers alumni feedback on the practicality of SD in the workplace to further improve SD integration in higher education institutions (HEI).

# 2 Methodology and Methods

This research employs both qualitative and quantitative approaches, and the data is collected simultaneously. This study uses a similar bottom-up approach that starts from students' and alums' perspectives to raise undergraduates' awareness of SD through survey questions. Lower-level stakeholders' perspectives, such as alumni, are considered as they better understand how curricula is taught compared to the university management (Lozano, 2006). This is because universities usually operate in a top-down approach which starts from the top management without the involvement of staff and students (Wang et al., 2020).

## 2.1 Quantitative Research

Engineering students from some of the Malaysian universities, particularly those from Monash University Malaysia, who voluntarily participate in an online survey questionnaire (Project ID: 37073). The aim is to assess their skills in SD and evaluate the limitations of the pedagogical approaches used. The survey includes learning outcomes related to SD in engineering modules to gauge students' knowledge of sustainability. Additionally, student preferences for pedagogical approaches, such as team-based projects, will be evaluated to enhance intellectual thinking and foster sustainability (Arefin et al., 2021). For the alumni survey, the frequency of dealing with sustainability issues in the workplace was examined mainly. It is to identify the importance of sustainability in the application of engineering practices.

### 2.2 Qualitative Research

After that, written interviews were used to get responses as it requires respondents to write their answers down instead of providing them verbally, allowing the responders to have more time to develop better responses. Students are required to provide feedback on their learning experience after incorporating sustainability assessment tools and the pedagogical approaches used. Alumni are targeted to understand how sustainability is incorporated in the workplace, providing valuable insights for educating students and preparing them for their future careers. Workplaces have high expectations from universities to integrate ESD into higher education (Arefin et al., 2021).

### 2.3 Method

Google Forms is utilized to create the questionnaire, including both qualitative and quantitative methods. The Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), will assess students' understanding of SD and Likert scale ranges from 1 (never), 2 (rarely), 3 (sometimes), 4 (often) to 5 (always) is used to measure the frequency of dealing with sustainability issues in terms of TBL aspects in the workplace. SPSS (Statistical Package for Social Sciences) statistics software is used for data collection and descriptive analysis to obtain mean ratings and standard deviations (SD) for each question. The mean range is characterized based on relevant literature (Ávila et al., 2017; Yuan et al., 2011; Tang, 2018; Tunji Olayeni et al., 2023). At the same time, Nvivo 20.3 software is used to process the data for the qualitative studies. This is because the software can organize, categorize and classify the text into different categories, allowing easier analysis of the unstructured text (Ávila et al., 2017).

## 3 Results and Discussion

### 3.1 Profile of respondents

A total of 160 responses from engineering undergraduates at XXXXXX University Malaysia were obtained, with 21.88% (N=35) coming from the civil discipline, 27.5% (N=44) from the chemical discipline, 24.38% (N=39) from the mechanical discipline, and 26.25% (N=42) from electrical and computing system engineering (ECSE) discipline. On the other hand, only 17 responses from alumni of various disciplines were obtained, with 41.2% (N=7) coming from civil engineers, 35.3% (N=6) coming from chemical engineers, and 11.8% (N=2) coming from mechanical and electrical engineers.

### 3.2 Undergraduates knowledge level of sustainability

The survey includes sections where respondents rate their level of agreement or disagreement with statements about achieving sustainability learning outcomes in environmental, social, and economic aspects. The reliability of the questionnaire was assessed using Cronbach's alpha test, which yielded high internal consistency values for environmental (0.93), social (0.844), and economic (0.929) factors.

The questionnaire with the descriptive markers and the outcomes were given in the tables below;

**Table 3.2.1: Questionnaire with their descriptive markers.**

| EN (Environmental) | SC (Social) | EC (Economic) |
|---|---|---|
| EN1- I have gained adequate knowledge in the ENVIRONMENTAL aspect of sustainability. | SC1-I have gained adequate knowledge in the SOCIAL aspect of sustainability. | EC1-I have gained adequate knowledge in the ECONOMIC aspect of sustainability. |
| EN2-I am able to use appropriate tools (e.g., ecological footprint) to measure the environmental impact produced by the products or systems. | SC2-I am able to use appropriate tools (e.g., Social Life Cycle Assessment) to measure the social impact produced by the products or systems. | EC2-I am able to use appropriate tools (e.g., Life Cycle Costing) to measure the economic impact produced by the products or systems. |
| EN3-I can provide energy-efficient solutions such as choosing processes with lower energy consumption or higher efficiency. | SC3-I am confident in communicating effectively with different disciplines or levels. | EC3-I am confident in coming up with an economic viability plan for a short-term project. |
| EN4-I know how to minimise the consumption of raw materials and resources during manufacturing construction. | SC4-I am confident to design a product system, or process that fulfills human needs. | EC4-I am confident in coming up with an economic viability plan for a long-term project. |
| EN5-I know how to include sustainable materials instead of traditional materials during the design stage. | SC5-I am confident in taking into account of health and safety issues involved in the projects. | EC5-I am confident to reduce the cost (e.g., human and material costs) of the project. |
| EN6-I am aware of the environmental impact of each process or product throughout its lifecycle. | SC6-I am confident in making decisions according to engineering ethical principles. | EC6-I am confident to make the project competitive in the market. |
| EN7-I know how to select and use suitable strategies to recycle, reuse or reduce waste generated. | | |

**Table 3.2.2: Mean and SD for learning outcomes statement**

| Course | Chemical | | Civil | | Electrical | | Mechanical | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| EN1 | 4.02 | 0.549 | 3.66 | 0.838 | 3.19 | 0.943 | 2.87 | 0.894 |
| EN2 | 3.50 | 1.00 | 2.66 | 1.136 | 1.98 | 0.950 | 2.21 | 0.951 |
| EN3 | 3.93 | 0.661 | 3.20 | 1.052 | 3.50 | 1.132 | 2.62 | 1.091 |
| EN4 | 3.91 | 0.741 | 3.46 | 0.980 | 2.86 | 0.899 | 2.85 | 0.961 |
| EN5 | 3.98 | 0.821 | 3.43 | 1.037 | 2.52 | 0.838 | 3.10 | 1.119 |
| EN6 | 4.07 | 0.661 | 3.60 | 0.881 | 3.14 | 1.026 | 3.23 | 0.986 |
| EN7 | 3.93 | 0.661 | 3.69 | 0.832 | 2.93 | 0.867 | 3.33 | 0.806 |
| **Total** | **3.91** | **0.74** | **3.39** | **0.917** | **2.87** | **0.955** | **2.89** | **0.978** |
| **Description** | **Agree** | | **Neither agree nor disagree** | | **Neither agree nor disagree** | | **Neither agree nor disagree** | |
| SC1 | 3.80 | 0.765 | 3.17 | 0.954 | 3.33 | 0.846 | 2.95 | 1.075 |
| SC2 | 3.61 | 1.146 | 2.51 | 1.173 | 1.98 | 0.975 | 2.10 | 1.021 |
| SC3 | 3.75 | 0.839 | 3.74 | 0.78 | 3.41 | 0.885 | 3.40 | 0.777 |
| SC4 | 3.68 | 0.829 | 3.26 | 0.98 | 3.29 | 1.066 | 3.08 | 0.984 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SC5 | 3.95 | 0.746 | 3.66 | 0.906 | 3.62 | 1.035 | 3.44 | 0.852 |
| SC6 | 4.09 | 0.603 | 3.89 | 0.676 | 3.90 | 0.821 | 3.59 | 0.751 |
| **Total** | **3.81** | **0.838** | **3.71** | **0.925** | **3.25** | **0.941** | **3.09** | **0.918** |
| **Description** | **Agree** | | **Agree** | | **Neither agree nor disagree** | | **Neither agree nor disagree** | |
| EC1 | 3.66 | 0.776 | 3.17 | 0.954 | 2.93 | 0.947 | 3.05 | 1.146 |
| EC2 | 3.55 | 0.951 | 2.77 | 1.031 | 2.48 | 1.215 | 2.49 | 1.121 |
| EC3 | 3.66 | 0.861 | 3.14 | 1.004 | 2.62 | 1.188 | 2.85 | 0.904 |
| EC4 | 3.52 | 0.952 | 3.26 | 0.980 | 2.50 | 1.018 | 2.87 | 0.951 |
| EC5 | 3.61 | 0.813 | 3.54 | 0.852 | 3.41 | 1.138 | 3.46 | 0.942 |
| EC6 | 3.66 | 0.861 | 3.29 | 0.825 | 2.98 | 1.199 | 3.18 | 1.189 |
| **Total** | **3.61** | **0.871** | **3.20** | **0.944** | **2.82** | **1.122** | **2.98** | **1.048** |
| **Description** | **Agree** | | **Neither agree nor disagree** | | **Neither agree nor disagree** | | **Neither agree nor disagree** | |

Based on Table 3.2.2, civil engineering students show the strongest performance in achieving social learning outcomes. Mechanical and electrical engineering students also exhibit high mean scores for social learning outcomes, indicating effective communication and adherence to ethical standards during the design process. Civil and mechanical students prioritize waste reduction and energy-efficient solutions, while electrical students focus on sustainable energy and transportation solutions. In the chemical discipline, environmental sustainability receives the highest mean score, given the industry's potential environmental impact, with chemical engineering students also acknowledging economic and social sustainability achievements.

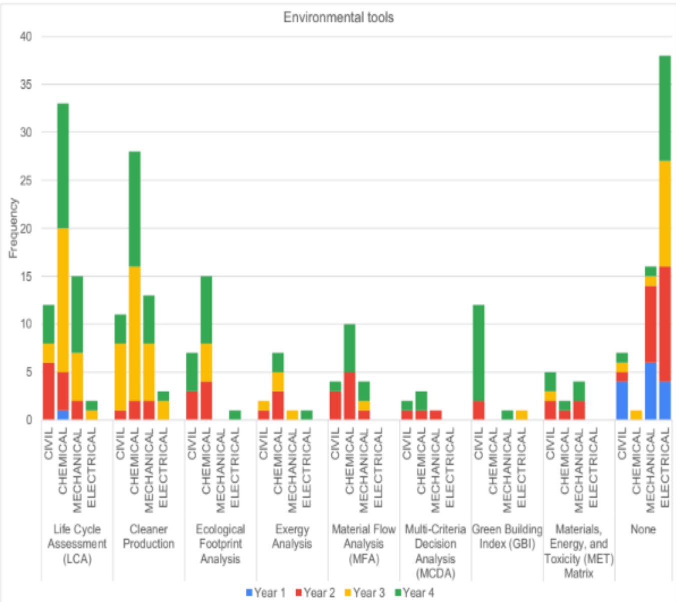


**Figure 3.2.1: Usage of environmental tools**

Figure 3.2.1 indicates that most electrical students lack the incorporation of environmental tools in their courses, leading to the lowest mean for EN2 in the environmental category. A similar trend is seen in civil and mechanical disciplines, where students neither agree nor disagree on the use of environmental tools (EN2, Table 3.2.1). In contrast, chemical, civil, and mechanical students who learned environmental tools from years 2 to 4 commonly use Life Cycle

Assessment (LCA) and cleaner production in their coursework. Additionally, more civil students used the Green Building Index (GBI) for environmental sustainability. However, first-year students, except those in the chemical discipline, are not yet taught environmental tools. Higher levels of study offer increased access to sustainability knowledge and tools (Tan et al., 2017).

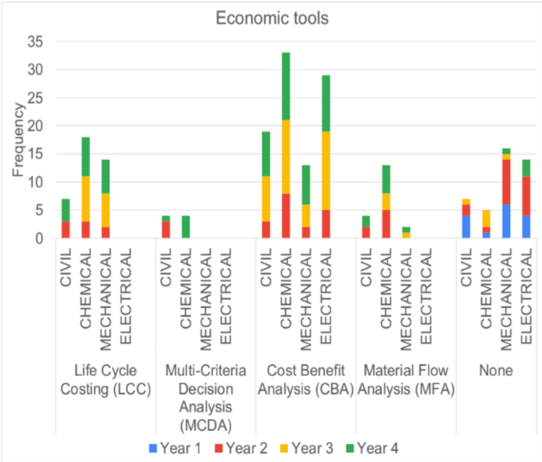


**Figure 3.2.2: Usage of economic tools**

Figure 3.2.2 shows that civil, chemical, and ECSE discipline students predominantly use cost-benefit analysis (CBA) to assess a project's economic feasibility. CBA helps stakeholders determine project viability by measuring benefits and costs in monetary terms (Myllyviita et al., 2017). In contrast, mechanical students use life cycle costing (LCC) more frequently to calculate the total life cycle costs of products, considering various factors like operation, maintenance, disposal, and environmental impacts (França et al., 2021).

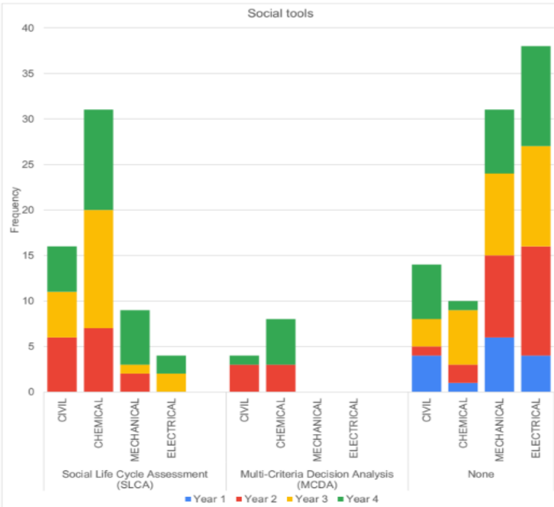


**Figure 3.2.3: Usage of social tools**

Figure 3.2.3 clearly indicates that the majority of mechanical and electrical students, along with half of the civil students, are not utilizing social tools. França et al. (2021) stated that the implementation of social tools is still lacking and also emphasized the need for a stronger theoretical foundation. Nonetheless, it is worth noting that some students from all disciplines have started using social life cycle assessment (SLCA), which is used to measure the impact across the entire life cycle of a product and processes to make more effective decision-making across a variety of industries and sectors, but it is not as established (D'Eusanio et al., 2019)..

## 3.3 Sustainability competencies in the industries

**Table 3.3.1: Frequency of dealing with sustainability issues**

| Course | Chemical | | Civil | | Electrical | | Mechanical | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Economic | 3.00 | 0.632 | 3.43 | 0.787 | 4.50 | 0.707 | 4.00 | 0.000 |
| **Description** | **sometimes** | | **often** | | **always** | | **always** | |
| Environmental | 3.67 | 1.033 | 2.86 | 0.690 | 3.00 | 0.000 | 2.00 | 0.000 |
| **Description** | **often** | | **sometimes** | | **sometimes** | | **rarely** | |
| Social | 2.83 | 0.753 | 3.29 | 0.756 | 4.50 | 0.707 | 3.50 | 0.707 |
| **Description** | **sometimes** | | **sometimes** | | **always** | | **often** | |

Table 3.3.1 highlights that chemical engineers frequently address environmental sustainability issues in their work. Alumni emphasize the need for comprehensive education in environmental science and climate change to tackle significant environmental impacts in their industries (Sanganyado & Nkomo, 2018). Civil and mechanical engineers commonly encounter economic issues, while electrical engineers consistently deal with economic matters.

## 3.4 Implications of findings

From the quantitative data of students and alumni from sections 3.2 and 3.3, it can be concluded that the workplace highly emphasizes economic sustainability, which stands as the lowest mean for the learning outcomes achieved by students. Hence, implications must be made to reduce the gap between competence needs by industry and the engineering syllabus taught.

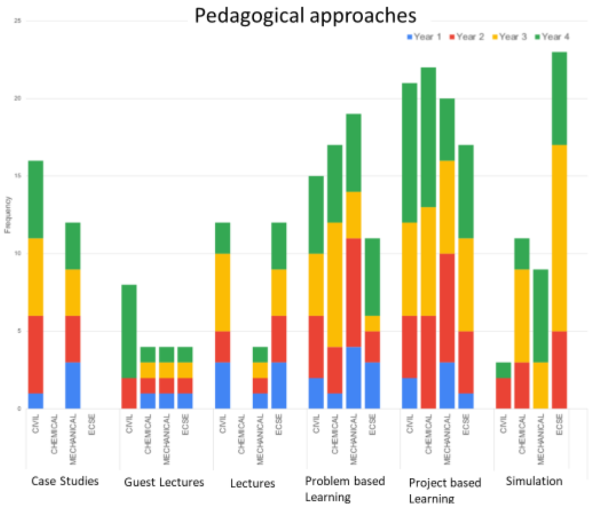


**Figure 3.4.1: Usage of Pedagogical Approaches**

Figure 3.4.1 shows that undergraduate students prefer active learning methods like case studies, guest lectures, problem-based learning, project-based learning, and simulation over passive learning approaches like lectures. Active learning has enabled students to expand their knowledge on sustainability issues, foster critical thinking, and apply theoretical knowledge to practical situations. Project-based learning, favored by civil, chemical, and mechanical students, has demonstrated significant improvements in academic knowledge, skills, and motivation, as well as effective group engagement (Thürer et al., 2018; Guo et al., 2020). Alumni recommend introducing more business case studies to help students visualize applying sustainable development in engineering decisions. An alumnus remarked, *"Sustainability should not be a fixed module; the taught process is more important."* This perspective suggests that sustainability knowledge can be integrated into relevant subjects rather than having a separate unit dedicated to it (Tunji-Olayeni et al., 2023). According to qualitative data, undergraduates and alumni find the design unit most relevant to sustainability, as engineering professionals increasingly incorporate sustainability principles into their work, benefiting the environment and society (Brunell, 2019). Prioritizing sustainability in education encourages creative thinking, designing products, processes, and services aligned with human needs. This unit offers an essential overview of engineering work in the business environment, focusing on TBL reporting in management, including financial, environmental, and social aspects. It emphasizes ethical behaviour, decision-making, and building a successful career while contributing to organizational success.

### 3.5 Limitations and future work

This research project has limitations, including the small number of participating universities and limited responses in section 3.1, making it difficult to determine if all engineering disciplines effectively implement TBL aspects in engineering education. The low response rate also hinders drawing conclusions about the frequency of dealing with sustainability issues in the workplace. Additionally, targeting universities from other countries, across Southeast Asia, can enhance sustainability aspects in engineering syllabuses.

Based on ANOVA test results conducted to assess the sustainability knowledge of engineering undergraduates across all levels. All learning outcomes were statistically significant with a p-value of less than 0.01, indicating a significant mean difference between the sustainability knowledge of engineering undergraduates at the beginning of their studies versus those at the end of their studies. To address this, a structured program should be implemented to equip all engineering undergraduates with necessary sustainability knowledge. Hadgraft & Kolmos (2020) suggest introducing sustainability to first-year students to establish a strong foundation for sustainability subject matters and facilitate its integration into design work in the future.

# 4 Conclusion

Addressing sustainable development is crucial to minimising or mitigating current environmental impacts. Higher education, particularly in engineering, plays a vital role in achieving this goal. A survey in Malaysian universities evaluated engineering students' sustainability competencies, primarily focusing on Monash University Malaysia. Results showed students possessed some level of sustainability competence. Civil, electrical, and mechanical engineering majors excelled in social learning outcomes and ethical decision-making. Chemical engineering students performed well in environmental sustainability due to dealing with greenhouse gas emissions (GHG) and energy consumption. Different engineering disciplines utilized various economic and environmental tools like CBA, LCC, LCA, and GBI. The quantitative data from students and alumni suggest that their workplace highly emphasized economic sustainability, which scored the lowest mean for student learning outcomes. However, the current teaching and learning needs improvisation on the sustainability integration in engineering education. This calls for measures to bridge the gap between competence requirements and the engineering syllabus taught. Engineering graduates must complete a professional practice unit to understand engineering work in the business environment, covering ethics, TBL reporting, and financial management.

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