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SUSTAINABLE ENGINEERING EDUCATION: ANALYZING PRACTICES IN MECHANICAL AND AIRCRAFT MAINTENANCE FINAL YEAR PROJECTS

Uma Devi Nadarajah[1*] and Vaina Malar Panneer Selvan[1]

[1]*Mechanical Engineering Department, Politeknik Banting, Selangor, Malaysia*
[*]*Corresponding author: uma@polibanting.edu.my*

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ABSTRACT

Sustainability has become a critical element of Technical and Vocational Education and Training (TVET), with future engineering professionals expected to address global environmental challenges. Final Year Projects (FYPs) serve as a key platform for students to demonstrate how well they understand and apply sustainability principles. This study examines sustainability practices in FYPs at the Mechanical Engineering and Aircraft Maintenance Departments of Politeknik Banting Selangor (PBS), using survey responses from 47 student groups. The analysis focused on students' awareness, the extent of sustainability integration, the aspects addressed, project contributions, and the challenges encountered. Findings show that more than half of the students reported a good understanding of sustainability, and 61.1% recognized its importance in engineering projects. Notably, 66.7% of Aircraft Maintenance students indicated full integration of sustainability, while Mechanical Engineering students more often reported partial adoption. Although many students engaged with sustainability—driven by project requirements or personal interest—the limited role of faculty guidance and institutional support reduced the depth of integration. By framing the results through Kolb's Experiential Learning Cycle and connecting them to Education for Sustainable Development (ESD), the study provides a novel perspective on how students not only acquire knowledge but also reflect on and act upon sustainability concepts. This contribution enriches the relatively underexplored TVET context and underscores the need for clearer guidelines, faculty training, and stronger industry partnerships to support meaningful sustainability integration. Future research should expand this work through longitudinal tracking of graduates and comparative studies across institutions.

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1. Introduction

Education for sustainable development, according to UNESCO 2017 is generally understood as learning that promotes changes in knowledge, skills, values, and attitudes, helping students and institutions build a more sustainable and fair engineering society. According to (Kelly, 2016), over the last 20 decades, the role of sustainability in engineering education have shown a significant increase where key findings of the study emphasizes the importance of integrating sustainability into engineering practice and education. Sustainability has become an important part of engineering education because engineers need to be able to deal with environmental, social, and economic problems. It also aims to combine human development with environmental concerns (Javier Bilbao, 2023). Over the past few decades, engineering programs have been adding more and more principles of sustainability to their courses to get students ready for these demands (Segalàs Coral, 2018). According to (Una Beagon, 2023), engineering students must be able to tackle complex, interdisciplinary, and socio-technical problems to fulfil the demand in sustainable engineering education. The growing integration of sustainability principles in engineering curricula reflects the urgent need for professionals capable of designing solutions that are economically viable, environmentally sound, and socially responsible (Mesa, 2017). Therefore, a comprehensive approach to education is essential, incorporating sustainability into engineering curricula. To build these skills, it is best to use active learning methods such as project-based and problem-based learning.

Over the past two decades, national education policies and worldwide imperatives such as the Sustainable Development Goals (SDGs) of the UN have contributed to the integration of sustainability into engineering education. As capstone projects in engineering programs, Final Year Projects (FYPs) offer a strategic opportunity to incorporate sustainable principles into student classroom instruction and practice. Project-based learning (PBL) and case studies are effective pedagogical tools for integrating sustainability into engineering curricula since they give students the opportunity to work on challenging, multidisciplinary problems that reflect professional practice (Mesa, 2017). This method encourages critical thinking and systems-level comprehension in order to develop sustainable engineering solutions. Malaysian polytechnics have been gradually incorporating sustainability principles to the curricula in order to produce graduates who can deal with environmental problems. This is in line with global goals involving the United Nations' Sustainable Development Goals (SDGs). A significant portion of current research focusses on undergraduate or graduate engineering programs in developed countries, often neglecting vocational and technical education settings, such as polytechnics (Jana Dlouhá, 2018,). This geographic and institutional gap leads to crucial enquiries regarding the universality and accessibility of sustainability education. For instance, in Malaysian polytechnics, the implementation of Program Learning Outcome 7 (PLO7) - understand and evaluate the sustainability and impact of engineering technician work in the solution of well-defined engineering problems in societal and environmental contexts, which relates to the environment and sustainability, is still evolving. There is limited empirical evidence regarding the effectiveness of these outcomes in being achieved through final year project 1 and 2 (FYP 1 and FYP 2).

In this research, mechanical engineering and aircraft maintenance engineering program were chosen because these are the programs offered at Politeknik Banting Selangor. PLO 7 is mapped to several theory and practical subjects for both programs, but not to the Final Year Project 2 (FYP 2), except for mechanical engineering, where FYP 1 (Project 1 – Proposal) is mapped to PLO 7. This presents an intriguing gap: how do students in these two distinct departments interpret, value,

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and apply sustainability principles in their projects? Do students merely follow project requirements, or because of an intrinsic motivation? Do supervisors rely on students' initiative or provide structured guidance? These are interesting questions that demand more research. Although the literature on sustainable engineering education is expanding, the specific practices, challenges, and outcomes related to sustainability integration in diploma-level FYPs, especially in diverse fields like mechanical and aircraft maintenance, remain largely under-researched. To close these gaps, this study has the following research objectives:

- To examine how sustainability is perceived and applied in Mechanical and Aircraft Maintenance FYPs at PBS.
- To identify challenges faced by students in integrating sustainability principles.
- To explore the role of institutional support and supervision in guiding sustainability practices.

The findings could potentially guide the development of technical and vocational education curricula, instructional strategies, and policy.

2. Methodology

The purpose of the study is to assess practices of sustainability among Polytechnic Banting Selangor students in the FYP. This study employed a quantitative research method, which enables the extraction of patterns (descriptive), problems (diagnostic), predictions (predictive), and prescriptions (prescriptive)—collectively, the 4Ps of data analysis. A structured questionnaire was distributed using Google Forms to semester 5 students pursuing Diploma Mechanical Engineering and Aircraft Maintenance departments at Politeknik Banting. The survey was aimed at collecting students' perceptions, practices, and understanding of sustainability in the context of their FYPs.

2.1 Survey Design

In quantitative research, particularly when conducting primary data collection, the use of research instruments is essential. According to (Lim, 2024) one of the most commonly used instruments is the questionnaire, which may include items that are adopted directly from prior studies, adapted from existing research to suit the current context (or newly developed to meet the specific objectives of the study. The questionnaire for this study was created specifically to evaluate sustainability behaviours among final-year diploma students in Politeknik Banting's Mechanical Engineering and Aircraft Maintenance departments. The instrument mainly consisted of closed-ended questions, with a few open-ended questions, and was constructed in accordance with relevant literature in sustainable engineering education, as well as chosen United Nations Sustainable Development Goals (SDGs). To ensure the questionnaire's validity and reliability, a two-step method was implemented. A pretest was administered to a small group of students to check the clarity, structure, and comprehensibility of the questions. The feedback from this pretest influenced adjustments that improved the final edition. Before distribution, the questionnaire was examined by two academic lecturers to ensure clarity, content relevance, and connection with the study's objectives. The final questionnaire had the following sections:

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1. Demographic Information – a total of 5 questions (closed and open-ended questions), including department, programme, and the focus area of the Final Year Project (FYP).
2. Awareness and Importance of Sustainability in Engineering Education – 3 closed-ended questions were given to assess students' understanding of sustainability concepts such as environmental impact, resource efficiency, and waste management.
3. Integration of Sustainability in FYP – 4 closed and open-ended questions to examine how sustainability was incorporated into their projects, including topic selection, design considerations, material usage, energy efficiency, and personal motivation for applying sustainable practices.
4. Challenges Encountered – 2 closed and open-ended questions were given to identify difficulties faced in implementing sustainable practices in their projects.
5. Improvement to Better Sustainability Integration in FYP – 3 questions comprise closed and open-ended questions to collect student suggestions for improving sustainability integration in future FYPs.

2.2 Data Collection Tool – Google Forms

For this study, Google Forms was selected as the primary tool for data collection due to its user-friendly interface, cost-effectiveness, and accessibility for both researchers and students at Politeknik Banting. According to (Jaiswal, 2024), Google Forms offers built-in data analysis features that present responses in the form of charts and graphs, making the data easy to visualise and interpret. To promote participation and assure data reliability, the questionnaire was brief and focused, with a preference for multiple-choice items to make completion easier. To protect participants' privacy and anonymity, personal identifiers such as email addresses were not collected. However, this choice limited the ability to track and prevent duplicate responses. Upon receiving management approval for the survey, the Google Form link was distributed to Final Year Project 2 (FYP 2) supervisors via official WhatsApp groups and email, along with clear instructions and a consent statement. The supervisors then shared the survey link with their students through FYP 2 WhatsApp groups. Participation was entirely voluntary, and respondents were assured of the confidentiality and anonymity of their answers.

2.3 Sampling and Respondents

In this study, sampling is the process of identifying and choosing a group of final-year diploma students from Politeknik Banting's Mechanical Engineering and Aircraft Maintenance departments to participate in the survey. This method is essential for the research since the sample selection has an immediate influence on the findings' accuracy, reliability, and generalisability (Lee, 2022). The study focused on Session I 2024/2025 students who were actively involved in their Final Year Projects (FYPs), ensuring that the data collected accurately reflected current sustainability practices and perspectives in engineering education. A non-probability purposive sampling strategy, namely convenience sampling, was used to select a particular group of students from both departments. This method, which is now considered standard practice in many educational surveys (Lee, 2022), allowed effective participant recruitment. The questionnaire was distributed to around 55 students who served as group leaders for FYP teams from both departments. Data were collected over a three-week period,

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from the end of October 2024 to mid-November 2024. The questionnaire was filled out by 47 different groups.

2.4 Data Analysis

In this study, the process of analysing quantitative survey data is divided into multiple interconnected steps, as described by (Ghanad, 2023). The first stage is to organise the data, which includes assigning numerical ratings, categorising responses, and entering it into analysis tools. The second stage is data analysis, which uses descriptive statistics such as percentages to summarise the findings. The results of this study are visually displayed using pie charts, tables and bar charts for easier interpretation. The final stage comprises presenting the results, which include not just visual representations but also a summary discussion that links the findings to current theories and literature.

3. Results

3.1 Demographic Distribution of Respondents (Student Groups)

Each respondent represented their Final Year Project (FYP) group, which typically consisted of three to four members, including the group leader who completed the survey. The first question in the survey asked student groups to choose their academic program—Diploma in Mechanical Engineering (DKM), Diploma in Mechanical Engineering (Manufacturing) (DTP), or Diploma in Aircraft Maintenance Engineering (DAM) to determine the demographic distribution. As shown in Figure 1, the distribution included 18 student groups from DKM, 20 from DTP, and 9 from DAM, making a total of 47 student groups in the survey. Most FYPs focused on design and development, where students were involved in hands-on construction and building engineering products

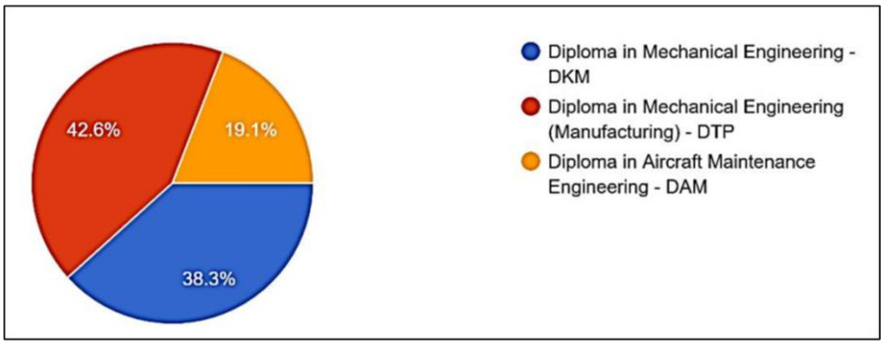

Figure 1. Student group representative participation in the survey by program

3.2 Awareness and Importance of Sustainability

This section sought input from student groups to reflect on three key aspects: whether they had received any formal education or training on sustainability in their department, their level of understanding of sustainability in engineering, and their perception of the importance of sustainability in engineering projects. Figure 2 illustrates the percentage of student groups from each program who received formal education related to sustainability during their studies. More than 50% of student groups from each program reported receiving formal education on

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sustainability, between Semester 2 and Semester 5, consistent with the structured integration of sustainability elements as stated in PLO7 in the Programme Information of all three programmes.

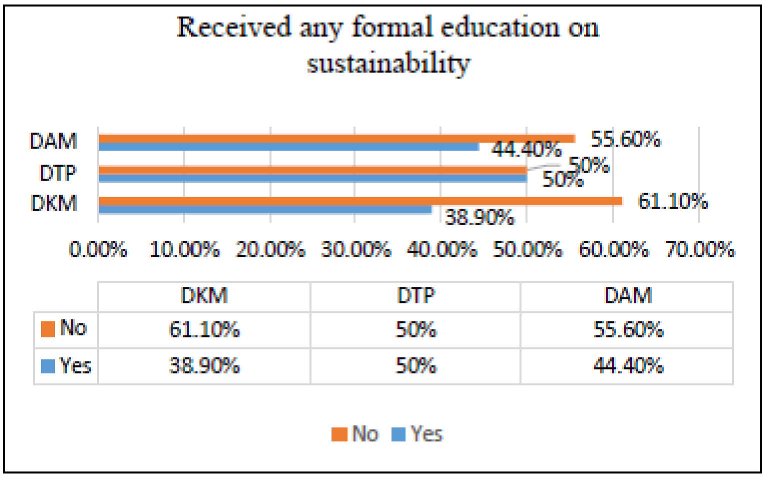

Figure 2. Receives of formal education for sustainability

Student groups mentioned some of the subjects that they learned about sustainability, as follows:

- DAM program - courses like Engineering Society, Human Factors, and Material Hardware, which cover environmental responsibility and human-centred design.
- DKM program - Engineering Society and Project 1, which connects engineering work to society and the environment, especially in project management.
- DTP program - Engineering Society, Project 1, Tool Design, and Jig and Fixture, which focus on efficient material use, resource management, and lean production.

However, student groups also identified several other subjects that related to the sustainability such as Communicative English 2, Human Factors, Material Hardware, Manufacturing Control, and Material Science. through which the students become aware of or understand concepts related to sustainability. These subjects are not directly assessed for PLO7 (sustainability-based engineering), but the contents of these topics may indirectly help in the development of the sustainability aspects of the individual student. For example:

- Material Science and Manufacturing Control introduce energy efficiency, waste reduction, and material selection.
- Human Factors supports sustainable design from a user-centred perspective.
- Communicative English 2 may raise sustainability awareness through assignments or discussions on environmental and social issues.

These results indicate that there is room for improvement in sustainability education through cross-curricular integration. These findings suggest that while sustainability is embedded in the curriculum across all three programs, the extent and delivery vary depending on the subject

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matter and instructional approach**,** confirming the need for continuous curriculum enhancement to ensure consistent and comprehensive exposure to sustainable engineering practices.

The self-assessed levels of understanding of the sustainability practices among student groups from three programs i.e.: DKM, DTP and DAM are presented in Table 1. Among all programs, most student groups rated their understanding level as good, and none rated it poor. A total of 1.1% of the students rated their understanding as fair in DAM, the only program below good in this question.

Table 1. Level of students' understanding of sustainability in engineering

Program	**Excellent**	**Good**	**Fair**
DKM	22.2%	77.8%	0 %
DTP	20.0 %	80.0 %	0 %
DAM	33.3 %	55.6 %	1.1 %

Table 2 shows that an average of 64.27% of the student groups from the three programs (DKM, DTP, and DAM) considered that sustainability is indeed a very important part of engineering projects. This high level of awareness likely correlates with the findings in Table 1, in which 71.13% of student groups have a good understanding of sustainability in engineering. This shows that the students have the knowledge of sustainable practices not only as an awareness, but that they value it by incorporating it into the real engineering world.

Table 2. Rating of students' consideration of how important sustainability is in an engineering project

Program	**Extremely Important**	**Very Important**	**Moderately Important**	**Slightly Important**	**Not Important**
DKM	22.2 %	61.1 %	16.7 %	0 %	0 %
DTP	25.0 %	65.0 %	10.0 %	0 %	0 %
DAM	33.3 %	66.7 %	0 %	0%	0%

3.3 Integration of Sustainability in FYP

This section of the questionnaire was designed to assess how sustainability is integrated into the FYP. It consists of three main questions which intend to reflect experiences and views of the student groups. The questions seek to determine to what extent sustainability concepts are integrated into their projects, which sustainability principles are embedded in their projects, the particular sustainability aspects they have incorporated such as sustainable material selection, energy efficiency, or waste reduction and the motivating factors that led students to include sustainability in their FYP, The findings from this section help to assess how well sustainability is understood, valued, and utilised by students in real-world engineering projects.

Table 3. Extent of sustainability integrated into FYP

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Program	**Completely Integrated**	**Partially Integrated**	**Not Integrated, but Considered**	**Not Integrated at all**
DKM	22.2 %	61.1 %	16.7 %	0 %
DTP	10.0 %	70.0 %	20.0 %	0 %
DAM	66.7 %	22.2 %	11.1%	0%

Table 3 represents the presences of sustainability elements related to FYP among three diploma subjects at Politeknik Banting. The data shows varying levels of integration across programs:

- DAM shows 66.7% completely integrated sustainability into their FYP which could be related to the nature of aircraft maintenance practices, where resource efficiency, waste minimization, and environmental safety are critical.

- DKM reported partial integration (61.1%) of sustainability. This reflects a moderate incorporation of sustainability elements, which may vary depending on project type or supervisor emphasis.

- DTP had the highest percentage of partial integration at 70.0%**.** Additionally, 20.0% mentioned that sustainability was considered but not integrated, suggesting that while students recognize sustainability's importance, it may not be systematically implemented in project execution.

Across all three programs, no group reported that sustainability was “not integrated at all, " reflecting a growing awareness and effort to address sustainable practices in technical projects. The fact that every group at least considered sustainability indicates a positive trend towards supporting FYPs with wider educational goals and national sustainability agendas.

Table 4 lists the major motivation factors that influenced student groups of the three diploma programs to integrate sustainability in the FYPs. The most frequently reported reason across all three programs was the requirement of the project followed by personal interest in sustainability. This indicates that sustainability wasn’t just encouraged in the majority of cases but was actively required in the project deliverables.

Table 4. Motivation for the inclusion of sustainability practices in FYP

Aspects	DKM	DTP	DAM
Project requirement	44.4 %	50.0 %	44.4 %
Personal interest in sustainability	38.9 %	35.0 %	44.4 %
Faculty guidance	11.1 %	10.0 %	0.0 %
Departmental policy	0.0 %	0.0 %	11.1 %
Other	5.6 %	5.0 %	0.0 %

Besides institutional requirements, a significant number of students were motivated by personal

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interest in sustainability. This was especially high among DAM groups (44.4%), compared to DKM (38.9%) and DTP (35.0%). These numbers point to the fact that sustainability is important to many student groups in the context of their future careers in engineering, which goes beyond what is formally required. However, faculty guidance was much less frequently reported as a motivator and no DAM groups chose this factor. This suggests that while faculty may provide project supervision, there might be little focus on sustainability unless instructed in the curriculum or project requirements.

Interestingly, only DAM groups (11.1%) indicated that departmental policy played a role in motivating sustainability integration. No DKM or DTP groups noted policy support, indicating a lack of clarity about how institutional sustainability frameworks are reported or implemented across departments. Lastly, a small percentage of student groups in DKM (5.6%) and DTP (5.0%) selected "Other" as their motivation, which may include external influences such as peer collaboration, industry exposure, or participation in competitions.

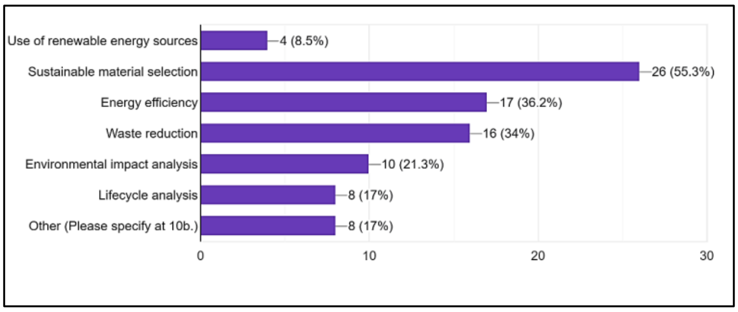

Figure 3. Sustainability aspects incorporated in FYP

The bar chart in Figure 3 presents the sustainability aspects that student groups incorporated into their Final Year Projects (FYPs), with responses gathered collectively from all three programs without department segmentation. Student groups could choose more than one aspect that is suitable for their project's focus. The most commonly integrated aspect was sustainable material selection, chosen by 26 students (55.3%). This reflects a strong awareness of the importance of material choices in engineering design, likely due to its direct impact on both cost and environmental sustainability. This suggests growing attention toward minimising excess materials and promoting lean engineering practices. The environmental impact analysis aspect shows that a smaller but significant portion of students attempted to assess the wider environmental consequences of their projects. The use of renewable energy sources had the lowest selection, with only 4 students (8.5%) indicating its inclusion. This reflects limited access to renewable technologies in the institutional setting, or the projects are more focused on mechanical and manufacturing components rather than energy systems.

3.4 Challenges in Implementing Sustainability in FYP

When considering the challenges faced by student groups in incorporating sustainability into their FYP, as shown in Figure 4, insufficient knowledge or expertise was the most reported challenge by student groups (59.6%), indicating a significant gap exists in sustainability-related

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competencies within the curriculum. Lack of resources, such as materials and funding, underscores the practical limitations that hinder sustainable project implementation. Time constraints were also a significant concern, suggesting that the integration of sustainability may require additional planning and effort beyond conventional project scopes. Besides that, student groups identified limited access to renewable energy technologies and a lack of institutional or faculty support as challenges to their sustainability efforts.

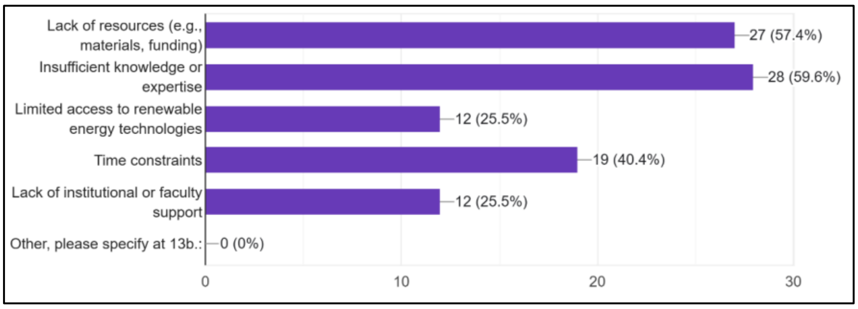

Figure 4. Challenges in integrating sustainability in FYP

Student groups adopted different approaches to overcome the issues they faced when incorporating sustainability into the FYP, as illustrated in Figure 5. The most common approaches were seeking additional resources or funding and adjusting project scope or objectives, each selected by 57.4% of student groups. Additionally, student groups also reported collaborating with faculty or industry experts, underscoring the value of mentorship and institutional support in overcoming technical and knowledge-based barriers. A further 23.4% incorporated alternative sustainable practices, reflecting a willingness to explore innovative solutions when conventional methods were not feasible.

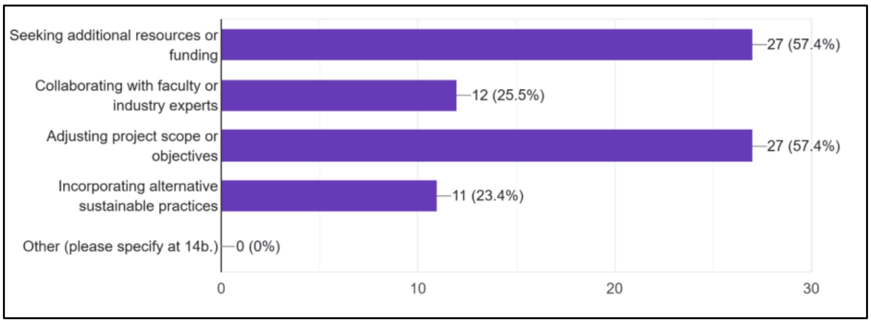

Figure 5. Suggestions to overcome the challenges

3.5 Challenges in Implementing Sustainability in FYP

In order to enhance the integration of sustainability into Final Year Projects (FYP), the student groups were asked to suggest improvements based on their experiences. The responses underline the importance of institutional involvement and resource allocation in assisting and supporting student-led initiatives for sustainability, (Munaro, 2024) and this is consistent with findings that can be found in the literature that sustainability-focused education and capacity building are seen as a way to provide students with the necessary knowledge and skills. The

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most frequently recommended improvement, selected by student groups from all three departments, was to provide more access to sustainable materials and technologies, as illustrated in Figure 6. This reflects a common challenge in higher education, where limited access to sustainable infrastructure and tools can hinder the practical implementation of sustainability concepts (Munaro, 2024). The next popular suggestion was providing enhanced training and sustainability workshops.

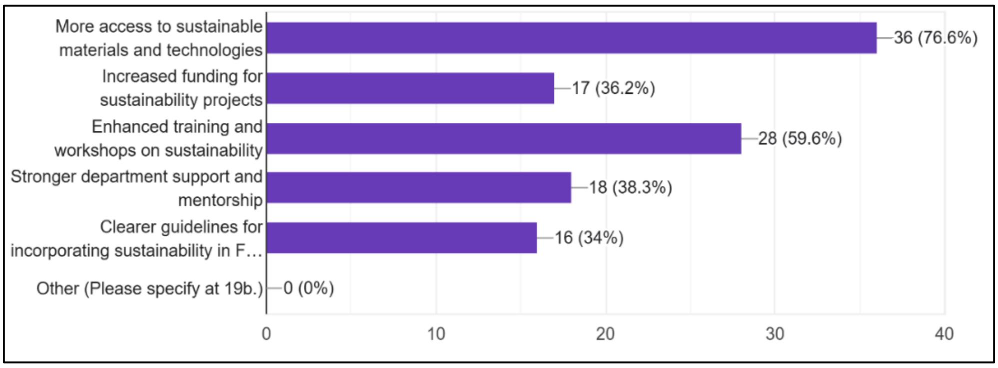

Figure 6. Suggestions to improve sustainability integration in FYP

The pie chart in Figure 7 illustrates the responses received from the student groups about the potential inclusion of sustainability as a compulsory component in Final Year Projects (FYP). The figure represents a clear indication of increased student awareness of the importance of sustainability in professional practice and is consistent with the global educational shift in support of the incorporation of sustainable development goals into higher education curricula.

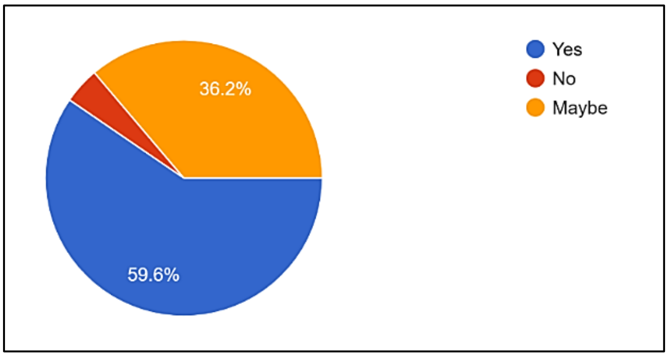

Figure 7. Suggestion to make sustainability a compulsory component in FYP

Student groups indicated "Maybe" (36.2%) to express a potential willingness to consider the plan, though possibly indicating that clearer implementation strategies and information regarding impact on project scope and feasibility are needed. Only 4.3% were against the proposal, which reflected little resistance to the idea. These findings suggest that student groups are largely willing to formalise sustainability in their project work, and that institutional efforts to make this more of a requirement could be well received, if funding and guidance are available to support it.

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4. Discussion

The outcomes of this study show how student groups across DKM, DTP, and DAM programs demonstrated strong awareness and understanding of sustainability, with the majority rating their knowledge as good or excellent. This aligns with earlier studies in TVET contexts, where students reported increasing familiarity with sustainability concepts when these were integrated into formal and informal curricula (Sivapalan, 2016)(Azmi, 2024). Remarkably, students in the DAM program exhibited higher levels of self-reported competencies, consistent with studies showing that program-specific integration of sustainability tends to produce stronger outcomes (Ralph, 2014). This result suggests that targeted embedding of sustainability within specialized modules such as Human Factors and Material Hardware may yield greater impact than generalized coverage across curricula.

The integration of sustainability into Final Year Projects (FYPs) was consistently acknowledged by students across programs, positioning FYPs as an effective mechanism for advancing sustainability education. Similar conclusions have been drawn in prior research, where project-based learning was identified as a key driver of sustainability awareness and application in engineering education (Hays, 2020); (Tafese, 2025). Our findings strengthen this claim, as students highlighted that FYPs provided opportunities to apply theoretical sustainability concepts to real-world engineering contexts. However, gaps in areas such as renewable energy and lifecycle analysis suggest that the integration remains partial. This mirrors earlier studies in TVET that identified a lack of depth in sustainability implementation due to resource constraints and the predominance of conventional mechanical and manufacturing projects (Sivapalan, 2016).
Institutionally, Politeknik Banting's cross-curricular exposure to sustainability—through subjects such as Engineering Society, Human Factors, and even non-technical courses like Communicative English 2—demonstrates the effectiveness of embedding sustainability both within and beyond technical modules. This resonates with findings by (Lavado-Anguera, 2024) who emphasized the value of multidisciplinary approaches and contextual learning in strengthening sustainability comprehension. Similarly, international research in sustainable engineering education stresses the importance of aligning curriculum design with global frameworks such as the United Nations Sustainable Development Goals (SDGs), particularly Goal 9 (Industry, Innovation and Infrastructure) and Goal 12 (Responsible Consumption and Production) (Ralph, 2014). The alignment observed in this study indicates that Malaysia's TVET vision is consistent with international trends that call for the integration of ethical and environmental responsibility into technical skill development.

At the same time, the challenges identified in this study—knowledge gaps, lack of resources, and limited institutional support- echo common barriers reported in the literature (Sivapalan, 2016); (Tafese, 2025). While students demonstrated adaptability in navigating these constraints, the findings highlight the need for stronger curriculum alignment, supervisory guidance, and resource allocation to ensure deeper integration of sustainability principles. Similar recommendations have been advanced by (Hays, 2020), who argued that faculty engagement and institutional investment are critical for expanding sustainability competencies among engineering students.

The findings of this study can be meaningfully interpreted through Kolb's Experiential Learning Cycle, which emphasizes the cyclical process of learning through concrete experience, reflective observation, abstract conceptualization, and active experimentation.

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Figure 8 illustrates how students' sustainability learning in Final Year Projects (FYPs) aligns with this cycle, complemented by Education for Sustainable Development (ESD), which underscores the interconnected dimensions of knowledge, skills, values, and action. This combined framework provides a lens for understanding both the progression of sustainability learning and the gaps that remain in the TVET context.

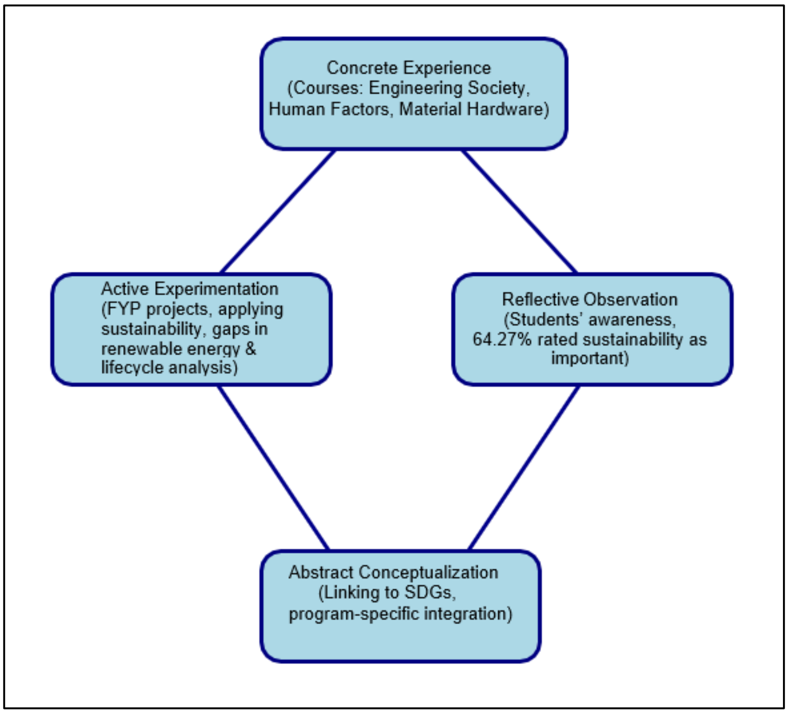

Figure 8. Integration of sustainability learning in Final Year Projects (FYPs) mapped onto Kolb's Experiential Learning Cycle.

At the concrete experience stage, student groups were exposed to sustainability concepts through diverse courses such as Engineering Society, Human Factors, and Material Hardware, in addition to indirect exposure in subjects such as Communicative English 2. These experiences created initial points of contact with sustainability beyond strictly technical contexts. According to the Education for Sustainable Development (ESD) framework, this aligns with the transmission of knowledge and skills as a foundation for sustainable learning. Through reflective observation, student groups demonstrated awareness of sustainability's importance in engineering practice, with 64.27% across programs rating it as "very important." This indicates the development of values and attitudes toward sustainability, a key dimension of ESD. Moreover, the higher level of reported competencies among DAM student groups shows how program-specific emphasis encourages deeper reflection tends to produce stronger outcomes (Ralph, 2014). These results suggest that targeted embedding of sustainability within specialized modules may yield greater impact than generalized coverage across curricula.

At the abstract conceptualization stage, students connected their coursework with sustainability principles, identifying its relevance to industrial challenges and the United Nations Sustainable Development Goals (SDGs), particularly Goals 9 and 12. This reflects their ability to integrate

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sustainability into their professional worldview, consistent with UNESCO's vision of ESD where learners critically examine and connect concepts to broader systems. Finally, the Active Experimentation stage was evident in student groups' efforts to embed sustainability practices into their FYPs. However, gaps emerged in areas such as renewable energy and lifecycle analysis, suggesting that while students attempted to apply their knowledge, resource limitations and project scopes constrained opportunities for innovation. This incomplete cycle highlights the need for stronger institutional support to enable students to test, refine, and expand sustainability practices in real-world projects.

Looking at the findings through Kolb's Experiential Learning Cycle and the view of Education for Sustainable Development (ESD), several practical steps can be taken to strengthen the way sustainability is integrated into engineering education, especially in Final Year Projects (FYPs).

1. Concrete Experience (Knowledge and Skills – ESD Dimension: Cognitive)

   Students need real exposure to sustainability issues, not just theory. This means:

   - Curriculum developers should embed sustainability-focused topics into both technical and general courses.
   - Lecturers can bring this to life with case studies, lab tasks, or field visits that let students experience sustainability challenges firsthand.
   - Policymakers should help create partnerships between institutions, industries, and communities, so projects are rooted in real-world problems.

2. Reflective Observation (Values and Attitudes – ESD Dimension: Socio-emotional)

   Experience only becomes learning if students stop to reflect. To make this happen:

   - Lecturers could include reflective journals or structured group discussions where students unpack the sustainability aspects of their work.
   - Curriculum developers might adapt rubrics to grade not only technical output but also the quality of these reflections.
   - Policymakers can back this up by encouraging accreditation systems that value reflective sustainability practices.

3. Abstract Conceptualization (Critical Thinking – ESD Dimension: Cognitive)

   Once students reflect, they need to connect their insights to broader frameworks and theories. This requires:

   - Curriculum developers aligning learning outcomes more explicitly with the Sustainable Development Goals (SDGs), especially SDG 9 and SDG 12.
   - Lecturers guiding students to build models or frameworks that link engineering solutions with sustainability principles.
   - Policymakers investing in lecturer training so they can confidently teach

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sustainability within technical contexts.

4. Active Experimentation (Action and Innovation – ESD Dimension: Behavioural)

   Finally, students should be encouraged to test their ideas and innovate. This can be done by:

   - Curriculum developers making sustainability a clear requirement in FYPs, for example through lifecycle analysis or efficiency metrics.
   - Lecturers providing tools like design thinking workshops, sustainability toolkits, or digital simulations that make experimentation easier.
   - Policymakers supporting with grants, resources, and industry collaborations so students' ideas can be conducted in real settings.

By cycling through experience → reflection → conceptualization → experimentation**,** students can gain not only technical knowledge but also the mindset and creativity needed for sustainable engineering. Embedding these practices ensures that TVET graduates are not only work-ready but also equipped to tackle global sustainability challenges in ethical and innovative ways.

5. Conclusion

This study explored how sustainability is currently being integrated into Final Year Projects (FYPs) among diploma students in Mechanical Engineering and Aircraft Maintenance Engineering at Politeknik Banting Selangor. While student groups generally showed an encouraging awareness of sustainability and its importance in engineering practice, our findings highlight a gap between intention and structured support. Sustainability often appeared in projects because of student initiative or formal requirements, rather than as part of a systematic framework guided by faculty or the institution. By framing student learning within Kolb's Experiential Learning Cycle and linking it to Education for Sustainable Development (ESD), the study contributes a novel lens for examining not only what students know but also how they experience, reflect, and act on sustainability concepts throughout their academic journey. This perspective highlights the importance of moving beyond knowledge transmission towards creating authentic opportunities for action, reflection, and application. What sets this study apart is its focus on diploma-level technical and vocational education, a level of education often overlooked in discussions of sustainability integration, which typically emphasize universities or industry training. By examining students' voices directly, we shed light on both the opportunities and the systemic challenges specific to TVET contexts. That said, we recognize the boundaries of our work: the data are self-reported, drawn from a single institution, and involve a relatively small group of student representatives. These limitations suggest the need for cautious interpretation, but they also open space for broader follow-up studies. Future research could track graduates longitudinally to see how sustainability practices carry into the workplace, compare practices across polytechnics, or bring in faculty perspectives to complement student insights. For practice and policy, the implications are clear. Institutions need to move beyond optional or ad-hoc efforts and treat sustainability as a core

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element of FYPs—potentially as a compulsory evaluation criterion. Faculty development programs, resource provision, and closer partnerships with industry can help ensure students are not left to navigate sustainability on their own. By embedding these supports, TVET institutions can play a stronger role in preparing graduates who are not only technically skilled but also ready to contribute meaningfully to sustainable development.

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