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CAN ECO-ENGINEERING MINDS BE ENHANCED? A STUDY OF MALAYSIAN POLYTECHNIC STUDENTS IN GREEN ENTREPRENEURSHIP EDUCATION

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Abstract:

The imperative for sustainable development has heightened focus on eco-engineering and green entrepreneurship. It investigates the role of the KAP Model in shaping students' eco-consciousness and entrepreneurial mindset. While environmental awareness is rising, there continues to be a dearth of developing effective eco-engineering minds, especially in entrepreneurship. As such, this study examines whether Malaysian Polytechnic students' eco-engineering mindset can be enhanced through targeted green entrepreneurship education. This paper addresses this gap by examining how cognitive, affective, and behavioural factors nurture sustainable attitudes of Polytechnic students. This quantitative research method used an online questionnaire to 155 students from 12 Polytechnics in Peninsular Malaysia. The data analysis conducted includes descriptive and inferential statistics for data using Statistical Package for Social Science (SPSS) Version 26. The data from a diverse sample of Polytechnic students in entrepreneurship courses allowed us to provide real-world insights into the impact of education on nurturing eco-engineering minds. The results revealed that the Knowledge, Attitudes, and Practices (KAP) Model was not significantly different in gender and Cumulative Grade Point Average (CGPA) scores of students on the KAP of green entrepreneurship. The study highlighted the opportunity for targeted pedagogical interventions to nurture eco-entrepreneurs among Malaysian and global students.

Keywords:

Attitudes, Green, Knowledge, Polytechnic, Practices

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Introduction

The global shift towards sustainable development has highlighted the importance of integrating environmental considerations into various sectors, including engineering and entrepreneurship. Sahoo et al. (2024) stated that as industries strive to reduce their ecological footprint, professionals increasingly need to combine technical expertise with sustainable business practices. This intersection has given rise to green entrepreneurship, which aims to create innovative solutions that address environmental challenges while generating economic value. In Malaysia, engineering education offers an opportunity to equip students with the necessary skills and knowledge to become eco-conscious entrepreneurs. Mechanical engineering students, with their technical background, are well-positioned to contribute to sustainable innovation. However, these students must develop a comprehensive understanding of environmental issues, sustainable technologies, and business principles to engage in green entrepreneurship effectively.

While the importance of green entrepreneurship is evident, its integration into engineering education faces several challenges, particularly in the Malaysian context. The effectiveness of entrepreneurship education in Malaysian polytechnics is generally low. According to Ismail and Ahmad (2013), students are not adequately equipped with entrepreneurial knowledge, skills, and attributes during their studies. The teaching approaches are deemed inappropriate, and polytechnic lecturers often lack relevant entrepreneurial skills, knowledge, or training (Ismail and Ahmad 2013). Numerous challenges occur during implementation. There is a growing interest in green initiatives and sustainability in Malaysian higher education institutions, including polytechnics. Muhiddin et al. (2023) Although most Malaysian public universities have implemented green initiatives, they face various obstacles to realising sustainable development goals and ensuring more sustainable practices. Given these challenges and the increasing importance of sustainability, researchers and educators advocate for a paradigm shift in entrepreneurship education. There is a need for improvement in the internal environment of Malaysian public universities, including polytechnics, to support entrepreneurship education. Othman, Hashim, and Ab Wahid (2012) indicate that from the student's perspective, the readiness for entrepreneurship education within the internal environment of public universities remains imperfect and requires enhancement.

These factors include lecturers' poor knowledge and entrepreneurial skills, inexperience, and lack of training and teaching approach mastery (Rengiah 2016). Despite these challenges, there is a growing recognition of the need to incorporate sustainability and green initiatives into higher education, including polytechnics. Thus, acknowledging the required shift in content and pedagogy, researchers implore an educational paradigm that teaches sustainability, systems thinking, integral entrepreneurship, and ethical concerns. The previous literature demonstrated that this shift positively affects students' entrepreneurial creativity, leading to favourable attitudes toward green awareness (Hameed et al. 2021). Furthermore, beyond intention, entrepreneurship education also influences students' entrepreneurial choices and mindset, incentivising them to participate in entrepreneurial activities (Li, Sun, and Gao 2022).

To address these challenges and capitalize on the potential of green entrepreneurship, a paradigm shift in entrepreneurship education is necessary. The stand on environmental education and its place in providing the foundation for polytechnic students to engage in business ventures that revolve around green initiatives and environmental sustainability is further reinforced through this study. Teaching planning and curricula should be integrated

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with green, low-carbon, and coordinated ecological development to promote eco-entrepreneurship education. This strategic incorporation creates a complete educational experience spanning the professional curriculum, the content of practical teaching, and entrepreneurial activities combined with ecological entrepreneurship content (Peng 2022). Furthermore, it highlights the need for students to be introduced to eco-innovation and entrepreneurship to possess better skills and understand what it takes to innovate opportunities in the green entrepreneurship model. The result of these initiatives, achieved with the integration of green entrepreneurship education within the course, is to equip students with entrepreneurial skills to generate awareness about sustainability and ethics and the importance of systems thinking in business (Nuringsih and MN 2022).

Given the importance of green entrepreneurship and the need for a paradigm shift in education, this study aims to address these issues in the context of mechanical engineering education in Malaysian polytechnics. Therefore, this study focused on diploma students from mechanical engineering at Polytechnics in Malaysia to furnish future eco-engineering students with relevant Knowledge, Attitudes, and Practices (KAP) for engagement in green entrepreneurship. By integrating green entrepreneurship education into the curriculum, students with a diploma in mechanical engineering will better understand sustainable development principles and practices. They will learn how to create profitable businesses while improving social, economic, and environmental conditions. This will empower students to identify the market potential for a sustainable business venture and seize it effectively.

Literature Review

Bandura Social Cognitive Theory (SCT)

Bandura's Social Cognitive Theory (SCT) complements the KAP Model by highlighting the interplay between cognitive, behavioural, and environmental factors in shaping learning and behaviour, which is particularly relevant to green entrepreneurship education (Bandura 2003; Beauchamp, Crawford, and Jackson 2018; Bussey 2023). Through observation and modelling, students acquire knowledge of sustainable practices by observing role models, such as lecturers or industry leaders, demonstrating eco-friendly business strategies (Bandura 2003; Connolly 2017). Self-efficacy, a key concept in SCT, aligns with the KAP Model's attitudinal component, as students who believe in their ability to succeed are more likely to adopt positive attitudes toward green entrepreneurship (Siddiquea et al. 2021). Outcome expectations reinforce this connection, as students who perceive tangible benefits, such as environmental preservation or economic gains, are motivated to practice sustainability. The reciprocal determinism in SCT, emphasising the interaction between personal beliefs, observed behaviours, and environmental factors, fosters a supportive learning ecosystem, encouraging applying green entrepreneurship knowledge into actionable practices (Ahmad et al. 2020; Pan and Pan 2020). By integrating SCT and the KAP Model, green entrepreneurship education can effectively nurture eco-conscious mindsets and behaviours among students, preparing them to lead sustainable initiatives.

Knowledge, Attitude, and Practice (KAP Model)

The KAP Model is designed to comprehend and assess individuals' knowledge, attitudes, and practices towards sustainability and green entrepreneurship (Kaliappan and Hamid, 2022; Okeke and Yong, 2016). The knowledge component in green entrepreneurship education recognises the individual's awareness of green entrepreneurship and sustainability concepts,

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such as environmental problems, sustainability practices, and the principles of green entrepreneurship (Domínguez-Valerio et al. 2019; Kuchinka et al. 2018; Ye et al. 2020). However, multiple studies have revealed that numerous green entrepreneurship programs do not holistically cover the content of sustainability practice and environmental science (Handayani et al. 2020; Safari et al. 2018; Tarekegne and Gelaneh 2019; Del Vecchio et al. 2021; Yasir et al. 2023). As a result, students may need a thorough understanding of sustainability principles, thus restricting their ability to innovate and implement green practices in their businesses effectively. This lack of knowledge can prevent them from realising the full potential of green entrepreneurship.

The representation of attitudes comprising beliefs, values, and perceptions of an individual towards green entrepreneurship and sustainability is the second component of green entrepreneurship education (Gan et al. 2022; Jung and Lee 2020; Kardos, Gabor, and Cristache 2019; Ramayah, Taghizadeh, and Rahman 2022; Riskos et al. 2021). This includes attitudes towards protecting the environment, motivation and interest in green entrepreneurship, and willingness to adopt sustainability practices in business ventures. Several educational programs focus more on technical and business skills, with less emphasis on nurturing supportive attitudes towards sustainability (Prabowo, Ikhsan, and Yuniarty 2022; Wei-Loon and Nordin 2019). Due to this, students may lack intrinsic motivation to prioritise sustainability in their business ventures, resulting in shallow engagement with green practices instead of a deep commitment driven by values.

Practice is the last component of the KAP model, which relates to the behaviours and actions towards green entrepreneurship and sustainability among students, as cited by (Ahmed et al. 2021; Gupta 2019; Zamfir, Mocanu, and Grigorescu 2017). While Polytechnics succeeded in getting graduates employed by creating entrepreneurs yearly, there is a lack of encouragement for students to practice entrepreneurship toward sustainability. The reason for this deficiency is a lack of consistent integration of green entrepreneurship in practical projects and case studies in the curriculum (Li et al. 2022; Mets, Holbrook, and Läänelaid 2021). As a result, students may not receive the opportunities they need for hands-on, project-based learning to explore and work with sustainable business solutions, creating a disconnect between understanding theories and real-world applications.

The KAP Model is gradually considered an essential means to analyse the preparedness and acceptance of students toward green entrepreneurship and sustainable initiatives. This model assesses students' KAP by identifying the gaps, misunderstandings, and areas that need intervention or education. Prior research (Anghel and Anghel 2022) Revealed that green entrepreneurship significantly influences young students. However, the study did not consider demographic variables such as gender and academic success. Although prior studies have considered gender differences, there is still a significant need for further research on how male and female students differ in their perceptions of green entrepreneurial education programs (Butkouskaya, Romagosa, and Noguera 2020; Jung and Lee 2020). Hence, focusing on these challenges could enhance green entrepreneurship education programs in training students to become informed, motivated, and capable entrepreneurs who will put sustainability at the forefront of their business activities. Moreover, achieving this goal requires embedding full content, nurturing a positive attitude, offering experiential learning, and applying robust assessment strategies.

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Thus, the primary objective of this research is to investigate the Malaysian Polytechnic students' KAP of green entrepreneurship education. The information gained on students' knowledge, attitudes, and practices regarding green entrepreneurship is fundamental, as these young people will be responsible for environmental protection and conservation. Moreover, the information obtained from this study could be helpful for policymakers, ecological learning program designers, and lecturers. Therefore, this study attempts to answer the following research questions:

1. Can eco-engineering minds be enhanced among Malaysian Polytechnic students in mechanical engineering through focused KAP of green entrepreneurship education?
2. Does the KAP of green entrepreneurship education differ between genders of mechanical engineering students at Malaysian Polytechnics?
3. Does the KAP of green entrepreneurship education differ among CGPA scores of mechanical engineering students at Malaysian Polytechnics?

To address these gaps, the authors propose the following null hypotheses for these research questions:
H_{o1}: There is no significant difference in KAP of green entrepreneurship education between the genders of mechanical engineering students at Malaysian Polytechnics.

H_{o2}: There is no significant difference in KAP of green entrepreneurship education among CGPA scores of mechanical engineering students at Malaysian Polytechnics.

Research Methodology

This research study used a quantitative methodological approach after conducting a pilot investigation. The central aim of the research design was to present targeted and specific questions regarding the KAP of diploma engineering students towards green entrepreneurship education in Polytechnic Malaysia. A survey was conducted to gather quantifiable data fairly and impartially, and the results were analysed using statistical methods. We implemented the survey design of our study to assess the KAP levels regarding green entrepreneurship among a sample of students from 12 Polytechnics in Peninsular Malaysia.

Sampling

The study population comprised diploma-level mechanical engineering students undertaking entrepreneurship courses from 12 Polytechnics in Peninsular Malaysia. A total of 155 students were selected using cluster random sampling, as determined by (Krejcie and Morgan 1970) sampling table. Cluster random sampling is a form of probability sampling that is practical when the complete population list is unknown, but information about larger groups is available (Tillé 2020). This method enables surveys without a complete population list, reducing costs and simplifying organisation. In this study, 21 to 22 students from each Polytechnic were selected to ensure a balanced representation. The students were surveyed using Google Forms questionnaires administered by their lecturers.

Instrument

The study used a set of questionnaires adapted from the previous research (Kaliappan and Hamid 2022; Kaliappan, Hamid, and Madar 2023). The questionnaire consisted of Sections A, B, C, and D. Section A collected respondents' demographic information, while sections B, C, and D measured knowledge (10 items), attitude (10 items), and practices (10 items) variables,

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making a total of 30 items. The researchers ensured the validity and reliability of the questionnaire. Validity determines whether the research truly measures what it was intended to measure or whether the results are truthful. The validity of the instrument was established through face validity and content validity. In addition, the language experts confirmed that the language used in the questionnaire was suitable for the respondents' comprehension. Supervisors and senior lecturers also evaluated the questionnaire for their opinions. Meanwhile, content validity measures the intended variable and ensures that the items represent all possible questions about the content or skill (Chua et al. 2020; Cresswell and Cresswell 2018). At the same time, reliability refers to the consistency of results over time and their accuracy in representing the total population under study (Biasutti and Frate 2017; Cohen 1988; Kahando and Mungai 2018; Köhler and Hartig 2019; Mahmood et al. 2020; Mallah et al. 2022; Salkind 2016; Schelfhout, Bruggeman, and De Mayer 2016; Taber 2018; Yang 2023). The questionnaire's reliability was assessed by conducting a pilot study with 54 Polytechnic students in the mechanical engineering program to measure internal consistency using Cronbach's alpha coefficient. Hence, a value greater than 0.6 is considered reliable (Berger and Hänze 2015; Taber 2018). The data obtained from the pilot study revealed reliability values of 0.67 for knowledge, 0.70 for attitude, and 0.71 for practices, demonstrating relatively high reliability for attitudes and practices while satisfactory reliability for knowledge.

Data Analysis

We employed statistical and logical methods to analyse, depict, assess, and interpret the data using Statistical Package for Social Science (SPSS) version 26 for descriptive and inferential statistics. The variables were denoted as knowledge (K1 to K10), attitude (A1 to A10), and practices (P1 to P10). Consequently, we implemented data cleansing procedures to rectify or eliminate incorrect, corrupted, improperly formatted, duplicated, or incomplete data within the dataset (Cresswell and Cresswell 2018). Lastly, we conducted a normality test using the Skewness and Kurtosis to ascertain whether the dataset conforms to a normal distribution and determine the appropriate parametric or non-parametric test usage. This survey utilised a 5-point Likert Scale and applied the mean score interpretation using three levels to evaluate the level of KAP among mechanical engineering students regarding Green Entrepreneurship education, as observed in Table 1. According to Wiersma (2000), scores falling between 3.68 and 5.00 indicate a very high level of agreement, while scores between 2.34 and 3.67 indicate a moderate level of agreement, and scores of 1.00 to 2.33 indicate a low level. Inferential statistics, specifically independent t-test and one-way ANOVA were employed to test the null hypotheses at a significance level of $\alpha = 0.05$.

Table 1 – Interpretation of mean value

Min Value	Interpretation
1.00 to 2.33	Low
2.34 to 3.67	Moderate
3.68 to 5.00	High

Source: Wiersma (2000)

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Results and Findings

Based on Table 2, the demographic analysis reveals that the study sample consists predominantly of young (86.5% aged 18-20), male (64.5%), and Malay (85.8%) participants, with a relatively even distribution across various Polytechnics. The CGPA distribution indicates a broad range of academic abilities, with the largest group (32.9%) having a CGPA between 2.68 and 3.00. Notably, 77.4% of participants need to gain prior experience in green entrepreneurship, highlighting a significant gap in practical exposure within this field. This demographic profile underscores the need for green entrepreneurship education to integrate more hands-on, experiential learning opportunities to prepare students for sustainable business practices. At the same time, the level of education and courses were equally distributed.

Table 2 – Respondents' Demographic Profile

Variables	Category	Frequency	Percentage (%)
Gender	Male	100	64.5
	Female	55	35.5
Age	18 to 20 years	134	86.5
	21 to 23 years	15	9.7
	24 to 26 years	0	0.0
	27 years and above	6	3.9
Ethnic	Malay	133	85.8
	Chinese	3	1.9
	Indian	19	12.3
	Others	0	0.0
CGPA	3.68 - 4.00	5	3.2
	3.33 - 3.67	27	17.4
	3.01 - 3.32	21	13.5
	2.68 - 3.00	51	32.9
	2.33 - 2.67	27	17.4
	2.01 - 2.32	15	9.7
	1.68 - 2.00	9	5.8
	1.33 - 1.67	0	0
	1.00 - 1.32	0	0
	0.99 and below	0	0
Experience	Yes	35	22.6
	No	120	77.4

Knowledge in Green Entrepreneurship Education

Figure 1 highlights students' knowledge of green entrepreneurship, revealing a moderate comprehension of various sustainability concepts. The highest mean score is for K9 (green marketing strategies) at 3.64, indicating that students grasp how green marketing promotes sustainable products and business success. Other strengths include K2 (sustainable supply chain management) at 3.61 and K6 (green entrepreneurship models) at 3.59. In contrast, K4 (environmental impact) has the lowest score of 3.39, showing students struggle to evaluate the environmental effects of business activities. K1 (green economy) scores 3.48, reflecting the limited understanding of sustainability within the broader economy. K3 (renewable energy technologies) and K5 (eco-design) score 3.54, suggesting some knowledge but room for growth. Variability is noted, particularly in K4 and K9, while K7 (regulatory frameworks) shows consensus among students (SD = 1.11). In summary, while students demonstrate a solid

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understanding of green marketing and supply chain management, they need more support in assessing environmental impacts and the green economy. Enhancing educational programs with hands-on activities, workshops, and industry partnerships could improve their knowledge.

Figure 1: Knowledge in Green Entrepreneurship

Sources: Adapted from Safari et al. (2018) and Niemczyk et al. (2023)

Attitudes in Green Entrepreneurship Education

Figure 2 highlights students' generally positive attitudes toward green entrepreneurship, with notable areas for improvement. The mean scores reflect strong agreement on the importance of sustainability and eco-friendly practices, particularly in A5 (environmental footprint), with a mean of 3.85. A10 (education in green entrepreneurship) and A6 (eco-friendly businesses) also received high scores, indicating that students value education in sustainability. However, A2 (passion for green practices) has a lower mean of 3.57, suggesting students' enthusiasm for sustainable practices is lacking. A4 (adopting sustainable solutions) and A3 (prioritising social impacts) show moderate support, indicating a need for greater encouragement to embrace sustainability fully. Variability in responses reveals inconsistencies; A8 (evaluate success impacts) and A2 show the highest standard deviations, reflecting differing levels of engagement. In contrast, A10 and A7 (responsibility for sustainability) exhibit less variability, with most students agreeing on the importance of education and responsibility. Overall, students have a positive view of green entrepreneurship, particularly regarding environmental and educational dimensions. To strengthen their passion and commitment, initiatives like workshops, mentorships, and real-world projects are recommended.

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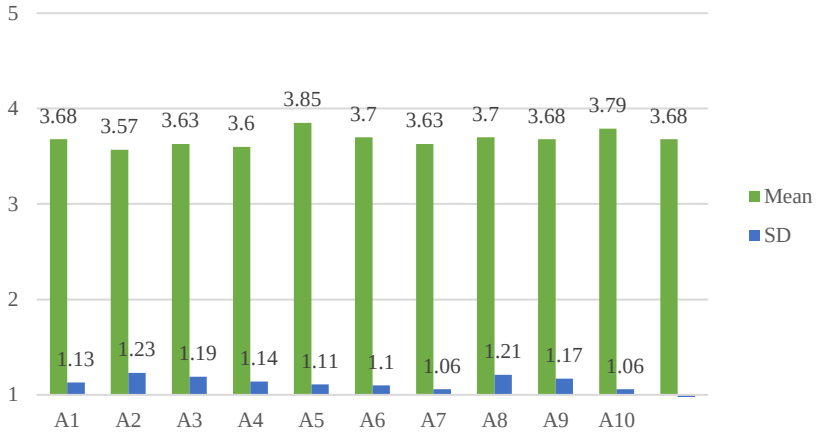

Figure 2: Attitudes in Green Entrepreneurship

Sources: Adapted from Gan et al. (2022); Riskos et al. (2021) and Kardos et al. (2019)

Practices in Green Entrepreneurship Education

Figure 3 evaluates green entrepreneurship practices, illustrating how individuals incorporate sustainability into their personal and business activities. The findings indicate a moderate level of engagement, with various mean scores highlighting strengths and improvement areas. The highest mean score is for P8 (support environmental initiatives) at 3.65, showing that students actively support community environmental efforts. Other strengths include P4 (willingness to learn sustainable practices) at 3.62 and P5 (seek information on green practices) at 3.61, indicating a readiness to gain knowledge in sustainability. However, there are noticeable gaps. P6 (use of environmentally friendly materials) has the lowest mean score of 3.43, suggesting inconsistent use of eco-friendly resources. P10 (educate and encourage sustainability) scores 3.50, reflecting a need for stronger advocacy, while P9 (consider environmental impact in projects) ranks at 3.52, indicating inconsistent prioritisation of environmental assessments. Responsive variability further underscores these gaps, with P10 showing the highest variability (SD = 1.32). In contrast, P2 (apply sustainability in projects) has the lowest variability (SD = 1.09), indicating more consistent sustainability practices. In summary, while students show moderate engagement in green entrepreneurship, there are clear opportunities for improvement, particularly in using eco-friendly materials, conducting environmental assessments, and enhancing advocacy efforts.

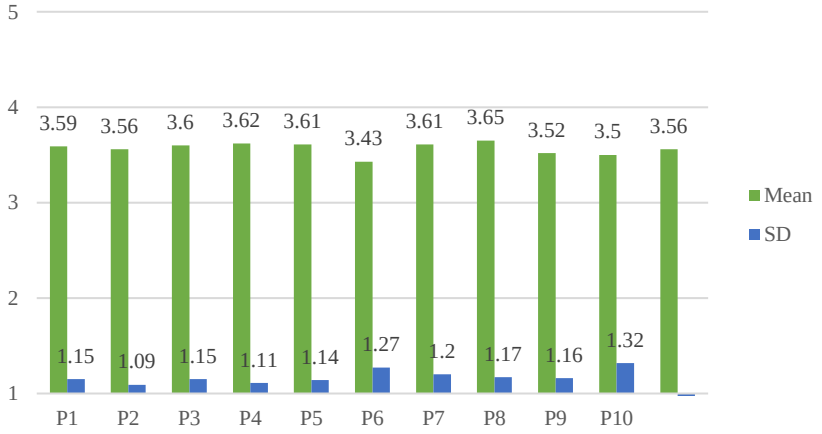

Figure 3: Practice in Green Entrepreneurship

Sources: Adapted from Kaliappan & Hamid (2022) and Nordin & Hassan (2019)

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Students' Gender and KAP of Green Entrepreneurship Education at Polytechnics

Based on the independent sample t-test, no statistically significant differences were discovered between the gender of the mechanical engineering students in terms of KAP. Furthermore, Levene's test for equality of variances indicated that equal variances can be assumed for all variables ($p > 0.05$). The t-test results indicated high p-values (0.96 for knowledge, 0.56 for attitudes, and 0.92 for practices), suggesting that the mean differences between genders were not statistically significant. The confidence intervals for the mean differences included zero, suggesting no meaningful differences between the groups' KAP related to green entrepreneurship. Thus, the null hypothesis (H_{o1}) was accepted.

Students' CGPA Scores and KAP of Green Entrepreneurship Education at Polytechnics

One-way ANOVA was conducted to examine the variations in KAP regarding green entrepreneurship among different CGPA score groups. The ANOVA findings indicate that there were no significant differences between groups for knowledge ($F(6, 148) = 1.14$, $p = 0.34$), attitudes ($F(6, 148) = 0.64$, $p = 0.70$), and practices ($F(6, 148) = 0.39$, $p = 0.89$). With all p-values exceeding the threshold ($p > 0.05$), it is evident that CGPA scores did not significantly influence students' KAP of green entrepreneurship. Consequently, the null hypothesis (H_{o2}) is accepted.

Discussion and Conclusion

Evidence from this study indicates that the level of knowledge regarding green entrepreneurship among mechanical engineering students at Polytechnics is moderate. The same scenario has also been reported in other studies worldwide. Earlier findings (Haldar 2021; Jaafar et al. 2017; Konys 2019; Li et al. 2023; Muhammad, Kamin, and Wahid 2019; Otterborn, Schönborn, and Hultén 2019; Prabowo et al. 2022; Purnomo et al. 2023; Qazi et al. 2020; Tarekegne and Gelaneh 2019; Valenga et al. 2023) discuss similar results regarding green entrepreneurship based on the low knowledge levels of their respondents. However, other studies discovered high knowledge (Bahri and Hasdiansa 2024; Din et al. 2020; Kim et al. 2023; Niemczyk et al. 2024; Safari et al. 2018; Tran 2024). The knowledge described by this study includes the tendency of students to understand green entrepreneurship as a solution to environmental issues related to ecosystems and natural resources. A possible explanation behind the moderate level of knowledge is the lack of comprehensive content about green entrepreneurship education, causing students to not fully understand the principles of sustainability, limiting their ability to innovate and effectively apply green practices in their businesses (Handayani et al. 2020; Safari et al. 2018; Tarekegne and Gelaneh 2019; Del Vecchio et al. 2021; Yasir et al. 2023).

At the same time, mechanical engineering students at Polytechnics were expected to possess a moderate to high level of attitude in considering the value and importance of incorporating sustainable practices in business. There is an ongoing debate on the concern that students' positive attitudes are greater, and superior compared to their knowledge levels. Nevertheless, the student's desire to be involved poses many questions and unfavourable uncertainties regarding these results (Ibrahim et al. 2015; Vuorio, Puumalainen, and Fellnhofer 2018; Yi 2021). These findings are consistent with several studies that discovered that students understand the importance of reducing ecological footprints and tend to integrate environmental considerations into decision-making processes (Krajnc et al. 2022; Mohiuddin et al. 2018; Pavlova 2017). Positive attitudes among students indicate that they value learning sustainable business practices and believe that education is crucial for preparing future business

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leaders to effectively address environmental challenges (Mustapha 2016; Valdiviezo et al. 2022). Surprisingly, some studies confirm that the attitudes of their respondents are moderate and unsatisfactory (Prabowo et al. 2022; Wei-Loon and Nordin 2019) regarding the awareness, importance, and value of integrating sustainable practices into business. These results further support the idea that environmental education must be incorporated into the curricula of primary and secondary schools. Early education shapes individual behaviour as students mature (Cai, Hussain, and Zhang 2022; Wei-Loon and Nordin 2019). These findings generally support other studies in this field that link knowledge with attitudes, as there is a strong relationship between these two variables, as also mentioned in several different studies (Li et al. 2023; Mohiuddin et al. 2018; Patwary et al. 2022; Pavlova 2017; Prabowo et al. 2022; Shabeeb Ali et al. 2023; Yasir et al. 2023).

This study also revealed that green entrepreneurship practices are moderate among mechanical engineering students at the Polytechnic. Although there is a level of commitment to green practices, there is room for improvement in how these practices are fully integrated (Safari et al. 2018; Del Vecchio et al. 2021). Another possible explanation for our findings is that individuals recognise the importance of sustainability but may face challenges in fully integrating these practices. Several similar studies suggest that green entrepreneurship practices are high (Asad et al. 2023; Cheliatsidou et al. 2023; Crosina et al. 2024; Gazali and Zainurrafiqi 2023; Lechuga Sancho, Martín-Navarro, and Ramos-Rodríguez 2020). However, some studies reveal practices below satisfactory levels (Ahmed et al. 2021; Mets et al. 2021). The reason behind the low level of green technology-related practices is that it is not easy for students. It is also supported that educational programs should incorporate more practical experiences that allow students to try and apply sustainable practices in real-world environments. In addition, it can involve project-based learning, industrial training, and collaboration with eco-friendly businesses (Domínguez-Valerio et al. 2019; Wei-Loon and Nordin 2019). Accordingly, it teaches students about using eco-friendly materials in their entrepreneurial efforts and provides ongoing support and guidance to enhance their commitment to green entrepreneurship.

Therefore, the KAP Model provides an initial approach to the green entrepreneurship perspective in different populations to explore the success or failure of initiatives promoting green entrepreneurship. The KAP model incorporates three pillars: KAP. The earliest model used to measure and explain environmental awareness and sustainability was proposed by Ramsey and Rickson (1976) regarding pro-environmental behaviour. The KAP model relates to cognitive, affective, and psychomotor elements subject to intervention from communication actions that enhance knowledge, change attitudes, and improve practices. However, this model cannot comprehensively explain the validity of behaviour (Ajzen 2015; Bandura 2004; Launiala 1970). Critics argue that shaping attitudes and behaviours towards environmental protection is more complex than traditionally understood. Moreover, it is believed that the KAP model fails to acknowledge that acquiring knowledge does not necessarily change attitudes, and changes in attitudes do not necessarily change behaviour. Ultimately, it would be a more comprehensive model if it could synthesise knowledge about sustainability and its various perspectives, the types of populations that share these perspectives, the types of attitudes that are most relevant, and the categories of human actions that through this perspective create a vision of sustainability and green entrepreneurship (Anghel and Anghel 2022; Niemczyk et al. 2024; Safari et al. 2018).

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In conclusion, this study investigates the knowledge, attitudes, and practices (KAP) of green entrepreneurship among mechanical engineering students at Malaysian Polytechnics, with the primary objective of determining whether eco-engineering minds can be enhanced through focused green entrepreneurship education. The findings reveal that students possess moderate knowledge and practice of green entrepreneurship, aligning with similar studies globally. This moderate understanding reflects the limited incorporation of comprehensive and practical content in green entrepreneurship education. However, students demonstrate a generally positive attitude towards sustainability, even though this enthusiasm does not consistently translate into practice. Addressing the research question, the study concludes that enhancing eco-engineering minds is achievable by embedding practical experiences, such as project-based learning and industrial training, into the curriculum to bridge the gap between knowledge and application. The KAP model underscores the interconnectedness of knowledge, attitudes, and practices while highlighting the challenges of translating knowledge into actionable behaviours. By adopting a more integrated and hands-on approach to green entrepreneurship education, coupled with government and institutional support in fostering a conducive environment for sustainability, the potential for nurturing future business leaders committed to green practices can be fully realised.

Limitations and Future Directions

The study has a few limitations stemming from its methodology and scope. First, the participants' sample size and diversity may limit representativeness to specific Mechanical Engineering students at a Polytechnics, resulting in a lack of representation from a wider demographic. This factor might limit the potential for the generalizability of the study's results to a bigger population of mechanical engineering students. Moreover, using self-reported data involves potential biases, such as social desirability bias, when respondents provide answers that they think are favourable rather than their original answers, especially regarding their knowledge and attitudes on green entrepreneurship. Another limitation is the cross-sectional study design of this research, capturing information at a single point in time. Although this design offers a snapshot of students' KAP concerning green entrepreneurship, it cannot test for causal influences or follow changes over time. Thus, longitudinal data would be better suited to measure the impact of green entrepreneurship education on students' behaviours and practices in the long run beyond the immediate survey time. Notably, geographical limitations are also relevant, with studies potentially focusing on Polytechnics in one region and overlooking regional differences in green entrepreneurship education and activities. Finally, while the survey analysed the curriculum, it may need to assess in detail the specific limitations or lacking areas in the content related to green entrepreneurship. Therefore, scholars must assess the KAP towards green entrepreneurship education in mechanical engineering and various engineering or STEM programs.

Several research areas have the potential to be further investigated concerning green entrepreneurship education among mechanical engineering students. At the same time, longitudinal studies, which track students' engagement over time, are useful in understanding how their KAP changes with further exposure to green entrepreneurship constructs. Experimental designs such as randomised controlled trials or quasi-experiments could generate causal associations on the effectiveness of specific educational interventions in changing student behaviours. A third important area for future research involves curriculum development and assessment. Developing rigorous green entrepreneurship curricula incorporating experiential learning components, including project-based learning and industry partnerships,

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will solidify students' ability to learn and apply sustainable practices in the real world. In addition, comparative research of different regions or countries may illuminate cultural and educational factors affecting students' engagement with green entrepreneurship. Technology integration is also a growing purview. Investigating whether augmented or virtual reality may improve green entrepreneurship education and nurture students' interest, resulting in high-level learning outcomes, represents novel educational strategies. Moreover, an interdisciplinary study combining mechanical engineering, environmental science, business, and ethics can offer an integrated view of green entrepreneurship and its sustainability implications.

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Appendices

Scale items.

Knowledge in Green Entrepreneurship

Items	Description
K1	I understand the meaning of a green economy and its application in business.
K2	I understand the concept of sustainable supply chain management and its importance in green entrepreneurship.
K3	I am aware of renewable energy technologies for business applications.
K4	I know the environmental impact of various business practices and technologies.
K5	I understand the role of ecological design in product development and its implications for sustainability.
K6	I am aware that green entrepreneurship is essential in the business model.
K7	I need to know the regulatory frameworks related to environmental sustainability and entrepreneurship.
K8	I understand the economic implications of integrating green practices into business operations.
K9	I understand that green marketing strategies are required to promote sustainable products.
K10	I know the life cycle analysis of products in sustainable business practices.

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Attitudes in Green Entrepreneurship

Items	Description
A1	I believe integrating environmental sustainability into business is essential for the future.
A2	I incorporate ideas of green practices into entrepreneurship.
A3	I prioritise social and environmental impacts alongside financial outcomes.
A4	I adapt innovative and sustainable solutions in future entrepreneurial endeavours.
A5	I consider the environmental footprint of products and services in business decisions.
A6	I believe that consumers increasingly prioritise businesses with eco-friendly practices.
A7	I feel responsible for contributing to sustainable development through my future career.
A8	I evaluate business success by considering environmental and social impacts.
A9	I believe green entrepreneurship can lead to innovative business models.
A10	I believe education in green entrepreneurship is crucial for preparing future business leaders.

Practice in Green Entrepreneurship

Items	Description
P1	I practice eco-friendly habits in daily life.
P2	I apply sustainability principles in entrepreneurial projects.
P3	I use recycled-based products in entrepreneurial projects.
P4	I am willing to learn about sustainable practices in the business environment.
P5	I actively seek information about green technologies and sustainable business practices.
P6	I actively use eco-friendly materials in business activities.
P7	I am willing to pay a higher price for eco-friendly products or services.
P8	I actively support environmental initiatives in the community.
P9	I consider environmental impacts in the final project for the entrepreneurship course.
P10	I encourage others to adopt sustainable practices in their entrepreneurial activities.

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