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JABATAN PENDIDIKAN POLITEKNIK DAN KOLEJ KOMUNITI

POLITEKNIK MALAYSIA
MELAKA

SMART GREEN

JILID 1

"EMERGING GREEN TECHNOLOGIES TOWARDS SUSTAINABILITY"

2025

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POLITEKNIK MALAYSIA MELAKA
UNIT PENYELIDIKAN INOVASI & KOMERSIALAN

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KANDUNGAN

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KATA ALUAN PENGARAH POLITEKNIK MELAKA

Dengan penuh rasa syukur dan bangga, saya merakamkan setinggi-tinggi penghargaan atas penerbitan Digest Smart Green, sebuah inisiatif penting yang mencerminkan komitmen kita terhadap kelestarian alam sekitar dan pembangunan hijau yang lestari. Penerbitan ini bukan sekadar wadah informasi, malah menjadi medium untuk kita menyampaikan idea, inovasi dan amalan terbaik dalam mewujudkan persekitaran yang lebih mampan.

Dalam era cabaran perubahan iklim dan pembangunan pesat, pendekatan *"smart"* dan "*green*" perlu dijadikan tunjang dalam setiap aspek kehidupan dan pembangunan modal insan.

Saya ingin mengucapkan terima kasih kepada semua pihak yang terlibat dalam menjayakan penerbitan ini dari para penyumbang artikel, pasukan editorial, hingga ke pembaca budiman yang menjadi inspirasi kami untuk terus berkarya. Semoga Digest Smart Green ini dapat memberi manfaat, mencetus kesedaran, dan menggerakkan tindakan demi masa depan yang lebih hijau dan lestari.

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Dr. Hjh. Shahiza binti Dato' Ahmad Zainuddin
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Bismillahirrahmanirrahim

Segala puji dan syukur ke hadrat Allah SWT kerana dengan limpah kurnia-Nya, Digest Smart Green edisi pertama ini berjaya diterbitkan.

Penerbitan ini merupakan satu inisiatif yang amat bermakna dalam usaha memupuk kesedaran dan amalan kelestarian alam sekitar dalam kalangan warga Politeknik Melaka dan masyarakat amnya. Ia juga sejajar dengan komitmen institusi pendidikan tinggi dalam menyokong agenda pembangunan mampan dan aspirasi negara ke arah teknologi hijau serta gaya hidup lestari.

Digest Smart Green PMK ini diharap menjadi platform perkongsian ilmu, idea inovatif, serta amalan hijau yang boleh dicontohi semua pihak. Ia juga mencerminkan semangat kerjasama, dedikasi, dan keprihatinan warga politeknik terhadap alam sekitar dan masa depan yang lebih lestari.

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KATA ALUAN KETUA KLUSTER JAMINAN KUALITI PEKA POLITEKNIK MELAKA

Melangkah hijau, menjulang visi global.

Penerbitan Digest Smart Green ini menjadi simbol kesungguhan Politeknik Melaka dalam mendepani cabaran kelestarian global melalui pelaksanaan teknologi hijau yang inovatif dan berimpak tinggi. Inisiatif ini merupakan sebahagian daripada strategi bersepadu kami untuk melonjakkan kedudukan institusi dalam UI GreenMetric World University Rankings, melepasi pencapaian tahun 2024 di tangga ke-999 dan mara dengan lebih yakin ke arah menjadi antara universiti teknikal paling lestari di dunia menjelang 2025. Sebagai peneraju JK Smart Green, Kluster Jaminan Kualiti komited memastikan setiap projek dan amalan yang dikongsikan dalam digest ini melalui penilaian menyeluruh dari aspek keberkesanan, impak serta pematuhan kepada piawaian kualiti dan kelestarian. Usaha ini selaras dengan tekad kami untuk memperkukuh budaya hijau secara sistematik, sekaligus mendukung transformasi Politeknik Melaka ke arah institusi yang progresif, mampan dan berorientasikan masa depan. Kami percaya bahawa Digest SmartGreen bukan hanya sekadar koleksi dokumentasi, tetapi merupakan sumber inspirasi — sebuah rujukan dinamik untuk warga akademik, pentadbiran, pelajar, serta institusi lain yang turut berkongsi aspirasi terhadap perubahan hijau yang lebih menyeluruh. Setinggi-tinggi penghargaan diucapkan kepada semua pihak yang telah menyumbang dalam menjayakan penerbitan ini. Bersama-sama, kita bukan sahaja mencipta perubahan — kita menggerakkan satu gelombang transformasi hijau untuk masa depan yang lebih cerah dan lestari.

"Bersama Melestarikan Kualiti, Menjana Masa Depan Hijau"

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Jawatankuasa Smart Green PMK dan Unit Penyelidikan, Inovasi & Komersialan (UPIK) komited untuk memperkukuhkan pelaksanaan Blueprint Smart Green PolyCC 2021-2026 (BSGPC) di Politeknik Melaka melalui kerjasama dengan Kluster Jaminan Kualiti, PeKA dan Unit Perpustakaan Politeknik Melaka. Bermula tahun 2025, matlamat utama SmartGreen PMK dan UPIK PMK adalah untuk MEMBUDAYAKAN AMALAN HIJAU melalui pelbagai aktiviti pendidikan antaranya penulisan ilmiah, penyelidikan dan pertandingan inovasi yang berkaitan dengan BSGPC. Dalam usaha memastikan penulisan Digest Smart Green lebih berimpak tinggi dan menepati objektif BSGPC, skop penulisan yang disusun dalam setiap jilid merangkumi bidang tumpuan berikut:

BIDANG TUMPUAN 1 (BT1)
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BIDANG TUMPUAN 2 (BT2)
PENGURUSAN TENAGA DAN PERUBAHAN IKLIM

BIDANG TUMPUAN 3 (BT3)
PENGURUSAN ALAM SEKITAR DAN LANDSKAP

BIDANG TUMPUAN 4 (BT4)
PENGURUSAN SISA

BIDANG TUMPUAN 5 (BT5)
PENGURUSAN AIR

BIDANG TUMPUAN 6 (BT6)
PENGANGKUTAN

BIDANG TUMPUAN 7 (BT7)
PEROLEHAN HIJAU

Dalam usaha meningkatkan kualiti hebahan artikel penulisan, penerbitan Digest Smart Green disusun mengikut jilid yang berbeza. Jilid 1 memuatkan 7 artikel sahaja. Manakala artikel lain akan diterbitkan dalam jilid seterusnya.

ULASAN KETUA JK INSTRUKTIONAL

Digest Smart Green 2025 ini memberikan gambaran umum yang baik tentang matlamat penghasilan digest yang menggabungkan konsep teknologi pintar dan kelestarian alam sekitar. Penulis berjaya menyampaikan isi utama kajian secara padat dengan penggunaan bahasa yang mudah difahami, sesuai dengan matlamat digest sebagai ringkasan ilmiah yang bersifat informatif dan cepat diakses.

Aspek positif yang signifikan dalam penulisan ini ialah kejelasan dalam mengenal pasti isu utama yang ingin disampaikan, seperti penggunaan teknologi pintar dalam pengurusan tenaga, pembangunan ruang lestari, serta potensi inovasi hijau dalam mempercepatkan agenda kelestarian. Dari sudut kekuatan kandungan, penulis menunjukkan tahap pemahaman yang baik tentang skop yang dikaji dan berjaya menyerlahkan konsep "Smart Green" dalam konteks global dan umum. Penekanan terhadap kepentingan integrasi antara teknologi dan ekologi mencerminkan persepsi tentang cabaran semasa yang berkaitan dengan perubahan iklim dan pembangunan mampan.Digest ini boleh dipertingkatkan dalam beberapa aspek antaranya penghuraian terhadap aplikasi sebenar. Penambahan contoh-contoh tertentu, seperti pelaksanaan inisiatif "Smart Green" di Politeknik Melaka atau projek berskala kecil yang berjaya, dapat membantu mengukuhkan kefahaman pembaca dan memberikan dimensi praktikal terhadap teori yang diketengahkan. Secara keseluruhan, digest ini merupakan usaha yang baik dalam meringkaskan isu kompleks secara padat dan berinformasi. Dengan sedikit penambahbaikan dari segi perincian kandungan dan penyusunan hujah, digest ini berpotensi menjadi sumber rujukan ringkas yang berkualiti dalam bidang teknologi pintar dan kelestarian.

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BIDANG TUMPUAN 1

PENGURUSAN PENDIDIKAN DAN PENYELIDIKAN

ENVIRONMENTAL SUSTAINABILITY AT WORK: DEFINING AND CONCEPTUALIZING EMPLOYEE GREEN BEHAVIOUR IN MANUFACTURING SECTOR

Bidang Tumpuan 1: Pengurusan Pendidikan dan Penyelidikan

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Abstract

This article explores the concept of employee green behaviour (EGB) as a vital component of workplace sustainability, particularly in the manufacturing sector. Protecting and conserving the environment is one of the 17 Sustainable Development Goals (SDG). As organisations prioritise environmental sustainability, it is critical to identify and promote employee behaviours that contribute to ecological responsibility. The study examines the EGB concept and its urgency. Finally, this paper emphasises the necessity of encouraging employee green behaviour as a means of accomplishing sustainable development goals and makes practical recommendations for organisations.

Keywords: Employee green behaviour, Environmental sustainability, Greening organizations

1. Introduction

Environmental sustainability become a critical issue for industries globally, with the manufacturing sector being a significant contributor to environmental degradation. In response, organizations are increasingly focusing on internal mechanisms, particularly employee behaviors, to foster sustainability. As part of the Paris Agreement 2015 and the United Nations Sustainable Development Goals (SDG), all countries should put in place appropriate policies and regulatory frameworks to drive the shift towards environmentally friendly lifestyles.

In Malaysia, statistic has confirmed this sector dominated the overall expenditure on environmental protection expenditure in 2021 which was RM2,486.8 million or 79.8 percent contribution (DOSM, 2023). The issues of environmental destruction have grown as a result of cumulative growth in the manufacturing sector (Yonget al., 2020). Additionally, the production process in manufacturing requires use of raw materials, energy, and water. The extensive usage of these resources has led to environmental and health problems (Fiedler, 2018).

Study on green practices is increasing due to the urge on policy and agenda toward environmental sustainability. For example, Lasrado & Zakaria (2020) have confirmed that green practices significantly benefit the environmental and business performance in the manufacturing industry. This is supported by Punj et al., (2023) and Zhang et al., (2021) who stated that green manufacturing practices help minimise the environmental impact. Similarly, Wang et al. (2021) revealed that green innovation practices have a positive impact on environmental performance.

2. Litrature Review

2.1 Defining Employee Green Behaviour

Due to the rising concern on environmental sustainability phenomenon, psychology and management scholars had studied on organisational behaviour and sustainability development in concentrating on employee behaviour (Ones & Dilchert, 2012; Paillé & Boiral, 2013; Yuriev et al., 2018).

Ones & Dilchert, (2012) among the prominent researcher that defined Employee green behaviour (EGB) as scalable actions and behaviour that employees engage in or linked and contribute to environmental sustainability at work. For example, the green practices such employee saving energy in the office, practising 3R activities (recycling, reusing, and reducing) and encourage colleagues to act more environmentally friendly. These activities, when practices an entire workforce can result in significant reductions in a company's overall environmental impact.

Accordingly, Norton et al. (2015) stipulated that EGB is a workplace-specific form of pro-environmental behaviour. The authors also emphasise two types of EGB required and voluntary. Required EGB is delineated as green behaviour performed within the context of employees' required job duties. It is also known as task-related EGB which includes obliging to organisational policies, changing methods of work and creating sustainable products and processes. The concept of required EGB is similar to task performance which is defined as the activities formally identified as a part of the job of a person that contributes to the technical core of an organisation (Bohlmann et al., 2018).

Meanwhile, voluntary EGB has been defined as green behaviour involving personal initiative that exceeds organisational expectations (Xiao et al., 2020). This is similar to the contextual performance and organisational citizenship behaviour (OCB). As stated by Organ et al. (2006), OCB is referred to as a set of discretionary workplace behaviours that exceed one's basic job requirements and often described as behaviours that go beyond the call of duty. In response with this concept, Boiral and Paille (2012) study organisational citizenship behaviour for the environment (OCBE) in examining the employee commitment on organisational sustainability.

2.2 Study Urgency

The increasing severity of climate change, resource depletion, and environmental degradation necessitates urgent action at all levels, including top management and employees. Organizations contribute significantly to carbon emissions, waste production, and energy consumption, making employee-driven sustainability efforts essential (Lamm et al., 2013). Therefore EGB is a vital mechanism through which businesses can mitigate their environmental impact by fostering a top down and bottom-up approach to foster environmental sustainability (Zen et al., 2016).

Moreover, governments and international organizations are tightening environ-mental restrictions, requiring companies to adopt sustainable business practices (Altassan, 2024). Compliance alone is insufficient; organizations must go beyond regulatory

mandates by fostering a workplace culture that empowers employees to engage in pro-environmental behaviors (Ali et al., 2019). Regulatory pressures are the most primary factor to motivate firms to implement environmental practices and be responsible for the effects of their activities on the environment.

Hence, studying EGB helps organizations develop strategies to align with evolving environmental policies while ensuring long-term sustainability. Though studies increasingly show employees as major drivers of environmental change, traditional corporate sustainability initiatives have concentrated on technological innovations and policy changes.

Organisations that promote EGB can gain a sustained competitive advantage by improving operational efficiency, enhancing business reputation, and increasing employee productivity (Abubakar et al., 2022). According to Oláh et al., (2020), organisations that have strong environmental policies and engaged staff outperform their competitors in terms of long-term financial performance and stakeholder confidence. Consequently, research on EGB assists firms in identifying effective green leadership strategies, incentive programs, and training interventions to maximise sustainability outcomes.

The urgency of studying EGB is particularly high in high-impact industries such as manufacturing, where energy consumption, waste production, and carbon emissions are substantial. According to Robertson and Carleton (2013), research in this field can provide practical insights into how employee behaviours support environmental sustainability and how businesses can successfully execute green programs.

3. Methodology

The methodology employed in this study is a literature review, focusing on the analysis of existing research on Employee Green Behavior (EGB) within the manufacturing sector. The study synthesizes previous studies, theoretical frameworks, and key findings to examine the factors influencing EGB, including leadership, corporate social responsibility (CSR), and Green Human Resource Management (GHRM). The study primarily relies on secondary data analysis through the review of published literature and theoretical discussions to conceptualize EGB in the context of workplace sustainability

4. Results and Discussions

4.1 Employee Green Behaviour Study in Manufacturing

As a world's second largest economy and largest manufacturer, this has resulted in worldwide pressure on Chinese organisations to solve environmental issues (Graves et al., 2013). Recent studies conducted in China have confirmed that EGB correlated with self-esteem and employee well-being in manufacturing, construction, and service industry (Zhang et al., 2021). Study by Zhang et al. (2021) aims to explore the EGB in manufacturing industries in China. Results of the study show that environmental

knowledge practices affect EGB meanwhile green perceived organisational support (GPOS) moderates the relationship. Similarly, Ture and Ganesh (2018) emphasise that organisational effort also plays a significant role on EGB among Indian manufacturing employees. In South Africa, Fatoki (2019) stipulated that the role of enjoyment and connectedness to nature has significance on EGB in SME organisation. Table 1 shows previous EGB study in manufacturing sector.

Table 1: Summary of the EGB study in Manufacturing

No	Author & Year	Tittle	Key Finding
1	Kanwal et al., (2024)	Corporate social responsibility : A Driver for green organizational climate and workplace pro-environmental behavior	CSR possitively cultivate the green behaviour among employee in medium-sized manufacturing firms in Pakistan.
2	Piwowar-Sulej et al., (2024)	Employees' eco-friendly innovative behaviors: Examining the role of individual and situational factors	Significant role of leadership and environmental awareness in manufacturing SMEs in Poland
3	Punj et al., (2023)	Mapping the field of green manufacturing: A bibliometric review of the literature and research frontiers	Increasing urgency for sustainable practices and the development effective sustainable practices, shaping policy decisions and fostering a globally competitive and environmentally friendly manufacturing.
4	K, (2023)	Green HRM and employee green behavior in the manufacturing firms: do psychological green climate and employee green commitment matter?	Revealed that GHRM impacts employees' green behaviour in India manufacturing.
5	Zhang et al., (2021)	How does employee green behavior impact employee well-being? An empirical analysis	Employee green behavior has a significant positive impact on self-esteem which in turn is converted into employee well-being in manufacturing industry in China.

No	Author & Year	Tittle	Key Finding
6	Davis et al., (2020)	Can Green Behaviors Really Be Increased for all Employees? Trade-offs for “Deep Greens” in a Goal-Oriented green HRM Intervention.	The role of Green HRM as an interventions on EGB among employees in an automobile manufacturing plant.
7	Yong, Yusliza, Ramayah, et al., (2020)	Pathways towards sustainability in manufacturing organizations: Empirical evidence on the role of green human resource management	Green recruitment and green training have positive effects on sustainability among employee in Malaysian manufacturing firms.
8	Yong, Yusliza, Jabbour, et al., (2020)	Exploratory cases on the interplay between green human resource management and advanced green manufacturing in light of the Ability-Motivation-Opportunity theory	Result from interview shows that Green human capital and green structural capital were greatly discussed by the human resources directors and managers in large manufacturing in Malaysia.
9	Ahmad et al., (2019)	A study of green factory practices in Malaysia manufacturing industry	Green Factory as effective tool for improving not only for environment performance but also for business performance and cultivate green behaviour.
10	Ture & Ganesh, (2018)	Pro-environmental behaviours at workplace An empirical study in Indian manufacturing organizations	Individual characteristics as well as organisational efforts influence employees’ green behaviours

Sources: Authors database

5. Conclusion

As the environmental crisis worsens and restrictions, employees have an increasingly important role in advancing organisational sustainability. Employee Green Behaviour (EGB) research is vital since it enables organizations to go beyond simply satisfying standards and develop an environmental responsibility culture. Businesses, policymakers, and researchers can work together to develop frameworks that encourage employees to actively participate to sustainability efforts. With a better understanding of EGB, organisations may change from reactive compliance to proactive, meaningful environmental action, eventually benefiting both the environment and long-term commercial performance.

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INCORPORATING GREEN OFFICE PRACTICES INTO THE SYLLABUS: BRIDGING THEORY AND WORKPLACE SUSTAINABILITY

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Abstract

The integration of sustainability into educational curriculum is vital for preparing students to meet the current environmental issues in work settings. This study explores the incorporation of “green office” practices into the syllabus of OBM350 (Organizational Management Practices), a course offered to semester 5 students of the Diploma in Office Technology Management program. The study focuses on bridging theoretical knowledge with practical by requiring students to engage in company visits to observe and evaluate real-world green initiatives. Through surveys and observation, students assess how organizations implement green practices such as energy efficiency, waste reduction, paperless, and green procurement. The findings reveal that experiential learning through company visits enhances students’ understanding of green office concepts, fosters critical thinking about environmental sustainability, and equips them with actionable skills that applicable to future careers. Furthermore, this pedagogical approach strengthens ties between academia and industry, hence cultivate environmentally conscious among students who contribute meaningfully to workplace sustainability efforts in future. This paper underscores the importance of aligning educational frameworks by embedding green office practices into the curriculum, while offering insights for institutions seeking to enhance their programs through innovative teaching methods

Keywords: Green office practices, sustainability education, experiential learning

1. Introduction

Environmental sustainability has become a critical concern in modern business operations, requiring future employees to be well-versed in environmentally responsible practices. As organizations move toward more sustainable business models, higher educational institutions play a vital role in equipping students with the necessary knowledge, skills, and attitudes to support workplace sustainability (Mojilis, 2019). It is believed that universities have a vital role in reforming societies by teaching students to become future leaders with new information, competencies, informed decision-making, and the ability to establish sustainable communities (B Handoyo, I K Astina, 2021).

According to Chang & Lien, (2020), integrating sustainability goals into university curriculum is essential for providing the strategies to increase awareness, fostering environmental literacy and preparing students for the evolving job market.

The importance of achieving the 2030 agenda has increasingly become a priority for universities that put forward Sustainable Development as one of their key areas of development and have committed to embedding SDGs as core values and principles in their everyday teachings and activities (Ilham et al., 2019). Therefore, this article explores the significance of integrating green office practices into the syllabus, the structure and implementation of a green office assignment, and its broader implications for sustainability education. Additionally, the discussion will highlight how this initiative aligns with the (SDGs) and contributes to sustainability competency development among students.

The increasing understanding of the limitations and insufficiency of attributing academic performance to learning is the reason behind a transition in many educational institutions from the conventional teaching paradigm to an experiential approach. One effective approach to enhancing sustainability education is through experiential learning which is a pedagogy that encourages students to engage in real-world problems and develop solutions is through direct experience (Kolb, 1984). Experiential learning is a specific type of learning from life experiences and is frequently contrasted with classroom instruction and lectures. In this context, a Green Office topic was embeded into the course assignment and provides students with a structured opportunity to explore workplace sustainability by visiting organizations, surveying employees, and assessing green office practices (Bashirun et al., 2023). This initiative bridges the gap between theory and practice, allowing students to apply green concepts in future work settings.

2. Literature Review

2.1 Green Office practices into the syllabus

Higher education institutions are acknowledged as vital contributors to advancing sustainability through their research, teaching, and involvement in the community (Ilham et al., 2019). Across the globe, universities have been integrating sustainability into their programs to ensure that graduates possess knowledge of environmental stewardship and sustainable decision-making (Blok et al., 2015).

Incorporating green office practices into the syllabus helps students understand how sustainability is operationalized in organizations. A green office refers to a workplace that minimizes environmental impact through energy efficiency, waste reduction, sustainable procurement, and employee engagement in green initiatives (Aroonsrimorakot et al., 2019; Armitage et al., 2011). By actively participating in these practices, students confidently develop vital sustainability skills that employers readily seek in today's competitive job market.

Organizations are increasingly adopting Environmental, Social, and Governance (ESG) criteria as part of their business strategies, with office sustainability being a key component (Kim et al., 2021). Green office initiatives contribute to corporate sustainability goals, such as reducing carbon footprints, improving resource efficiency, and fostering a culture of environmental responsibility among employees (Fan & Fang, 2020). Some common green office practices include energy conservation, waste reduction and conservation, green procurement and employee engagement such as green training. By evaluating these practices in real-world settings, students gain insights into how sustainability policies are implemented and the challenges organizations face in maintaining green operations.

3. Methodology

The current study shows how the “Green Office” topic was mapping and integrate in the assignment that is designed as an experiential learning activity which encourages students to critically analyze sustainability efforts in organizations. The assignment is structured as follows:

1 P*reliminary Research and Theoretical Understanding*

Before visiting organizations, students engage in theoretical learning to understand key sustainability frameworks that coveres in class session, such as the introduction of green office, conservations of the energy and elements of office environment (lecture session in class). This phase is to ensures that students have the necessary background to assess green office practices effectively.

2. *Organizational Visits and Data Collection*

Students visit organizations to observe green initiatives and conduct interview and surveys with key person (sustainability managers, head of green committee) and employees. Key areas of assessment include:

- Energy efficiency measures (use of renewable energy, smart energy systems)
- Waste management program (recycling policies, reduction of single-use plastics)
- Water conservation initiatives (efficiency measures, awareness programs)
- Employee involvement in sustainability (green training, incentives for eco-friendly behavior, green procurement)

3. *Data Analysis*

Students analyze the collected data and preparing for the report by following the rubric and guidelines given. This phase helps students develop critical thinking and data interpretation skills.

4. Presentation

Students present their findings in reports by highlighting areas of excellence and potential improvements. They also enthusiastically share their experiences from the visit to the company, where they had the invaluable opportunity to observe real-world green practices in organizations.

4. Results and Discussions

This paper highlights the outcome as follows:

1 Enhancing Employability and Workforce Readiness

Employers are increasingly recognizing the importance of graduates with sustainability competencies. Research reveals that organizations are drawn to candidates who can effectively drive Environmental, Social, and Governance (ESG) strategies and lead impactful sustainability initiatives. The Green Office Assignment inspires and equips students to embark on rewarding careers in corporate sustainability, environmental consultancy, and green management, fostering a greener, more sustainable future for all.

2. Fostering Industry-Academia Collaboration

The assignment significantly enhances collaboration between universities and industry partners, driving meaningful knowledge exchange and building robust partnerships for sustainability research and internships. By engaging with real-world organizations, students gain invaluable professional networking opportunities that can propel their careers forward.

3. Encouraging Pro-Environmental Behavior Among Students

Experiential learning is a powerful catalyst for behavioral change. Students engaged in sustainability education are significantly more likely to embrace eco-friendly practices in their daily lives and future careers. By actively partnering with organizations, these students not only deepen their understanding but also emerge as passionate advocates for sustainability, influencing both academic circles and professional landscapes.

5. Conclusion

Integrating green office practices into the syllabus through experiential assignments provides students with valuable hands-on experience in workplace sustainability. By bridging theoretical knowledge with practical application, this approach enhances sustainability literacy, prepares students for green careers, and aligns higher education with global sustainability goals. Universities must continue evolving their curricula to include real-world sustainability learning that empowers the next generation of environmentally responsible professionals.

Incorporating the concept of a "green office" into a course syllabus can motivate students to become positive change agents in their future workplaces and communities. This approach fosters a sense of environmental responsibility and provides students with the knowledge and skills necessary to promote sustainability in their future careers.

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EMBEDDING GREEN WORK CLIMATE: PATHWAYS TO SUSTAINABLE ORGANIZATIONS

Bidang Tumpuan 1: Pengurusan Pendidikan dan Penyelidikan

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Abstract

This review article examines the concept of a green work climate and its pivotal role in fostering environmental sustainability within organizations. As global concerns about climate change and resource depletion intensify, organizations are increasingly adopting sustainable practices to align with environmental goals. A green work climate, characterized by policies, norms, and values that prioritize ecological responsibility, serves as a critical driver for encouraging employees to engage in pro-environmental behaviors. Through a comprehensive review of existing literature, this paper explores the pathways through which a green work climate influences employee attitudes, behaviors, and organizational outcomes. By synthesizing insights from multidisciplinary perspectives, this article provides actionable recommendations for organizations seeking to transition toward sustainable practices. It concludes by emphasizing the transformative potential of a green work climate in driving both environmental and organizational success, positioning it as a cornerstone for achieving sustainable development goals (SDG).

Keywords: Green Work Climate, Environmental Sustainability, Sustainable Organization Culture, Pro-Environmental Behavior

1. Introduction

As a result of global climate change, business stakeholders are increasingly concerned about aligning operations with worldwide environmental norms. Recent research has begun to bridge the gap between general and employee green behavior by applying specific behavioral models to the working context. Over the last decade, there has been a substantial increase in the research on green practices adopted by individuals in working contexts. The environmental issue led to the increasing trend in research on related behavior. According to the Environmental Protection Survey Report 2020, industry players in Malaysia spent RM2.89 billion on environmental protection in 2019, a 7.0% increase over the amount spent in 2018. Environmental behavior is being studied with the various antecedents, to see the importance and its effect on employee behavior on environmental sustainability. Therefore, the purpose of this review is to systematically evaluate and synthesize the existing literature in investigating the trend of organizational climate that intervenes in green behavior.

2. Literature review

2.1 Organizational Climate

Organizational climate is considered an important contextual factor that reflects employees' attitudes and behaviors (Khang et al, 2016). Moreover, organizational climate determines individual and group attitudes to reinforce positive work behavior (Garcia-Garcia et al., 2011). On the other hand, work climate is defined as employees' impressions of the activities, procedures, and behaviors that are rewarded, encouraged, and predicted that influence employee behavior (Schneider, 2000).

The assimilation of the environmental values and practices within the organization will also affect the organization performance (Fraj et al., 2011). With growing pressure to improve the environmental performance, instilling the green work climate in the organizational system becomes a business agenda and main focus by the stakeholder. The lack of contribution and support from top management; difficulty in accessing resources; and resistance from employees were the main challenges experienced during environmental practice within the organization (Zutshi et al., 2008). Hence, a green work climate requires coordination from all the departments to achieve the targets. Green programs for instance waste, water, and energy-savvy programs must be practiced at each level within the organization. These mutual and shared values can inculcate and encourage the employees to foster the new green work climate. On the other hand, Cronin, Smith, Gleim, & Ramirez (2011) reported that there is a growing interest among top managers and stakeholders on environmental implementation as a business agenda.

Organizational climates have been proved in influencing employee attitudes and behaviors as well as specific organizational outcomes such as organization performance (Kuenzi & Schminke, 2009). Concerning the organizational climate, the concept of "green work climate" which applies to the organization to achieve the environmental sustainability agenda through incorporating environmentally friendly policies. Norton et al., (2016) detailed the contextual factors including the institutional, organizational, team, and leader that contribute and shape the employee green behavior. Consequently, the perceptions of green work climate may serve as a psychological mechanism related to certain organizational policies and employee behavior.

2.2 Green Work Climate

Ones and Dilchert (2005) expressed that green work climate is the employee perception regarding green organizational policies, procedures and practices which are similar to organizational missions, objectives and strategies in an environmentally friendly workplace. Based on organizational climate notion, Norton et al., (2014) introduced the concept of green work climate (GWC) grounded from the concept of employee work climate perceptions that is constructed from theory of normative conduct (TNC) (Cialdini et al. 1990) which focuses on the extent to which behavior is considered socially acceptable. Following (Norton et al., 2014) defined GWC as employees' perceptions and interpretations of their organization's policies, procedures, and practices concerning the organization's environmental sustainability.

Moreover, the terms, ‘green psychological climate’ (Saleem et al., 2020; Zhou et al., 2018), ‘pro-environmental work climate’ (Robertson & Carleton, 2018), ‘green organizational climate’ (Zientara & Zamojska, 2018) and ‘green work climate’ (Choong et al., 2020; Dahiya, 2020; Norton et al., 2014) are used interchangeably. Nevertheless, all these concepts contribute to similar outcomes, for example in greening organization and strategy (Flagstad et al., 2021), green product development performance (Zhou et al., 2018) and fostering green behavior at work (Sabbir & Taufique, 2021).

Previous scholars argued that employees working in organizations with more positive climate are more likely to be satisfied with their jobs (Ahmad et al., 2018). Most organizations have multiple work climates that work concurrently and help employees, inspired to succeed, and to recognise which behaviors they are expected to perform (Schneider et al., 2013). In the green behavior context, research suggests that organizations with strong pro-environmental work climates were reported higher rates of employee green behavior employee and tend to committed on environmentally friendly when realize their colleagues engaging in such behavior (Norton et al., 2017). Similarly, A. Kim et al., (2014) found that employees engaged in more environmental friendly behavior when they perceived that environmental management was integrated with human resource functions such as training and performance appraisals

3. Methodology

This article is a review paper that examines the concept of a green work climate and its role in fostering environmental sustainability. It does not involve primary data collection (such as surveys or experiments) but instead synthesizes findings from previous research.

4. Results and Discussions

4.1 Green Work Climate Measurement Scale

Majority of the study were measured with scale validated by Norton et al. (2014). There are eight-item instrument with two dimensions, namely, perceptions of green work climate of organizations and co-workers. This scale focusses upon the perceptions of employees regarding the implementation of practices, processes and policies of environmental sustainability in day today work life. The sample item for perceptions of green work climate of organizations is “Our company believes it is important to protect the environment” and for perceptions of green work climate of co-worker is “In our company, employees try to minimize harm to the environment.” The responses were taken on five-point Likert-type scale varying from “strongly disagree” (1) to “strongly agree” (5).

Table 1.: Green work climate measurement scales

Green work climate of organizations		**Green work climate of co-workers**	
1	Our company is worried about its environmental impact	1	In our company, employees pay attention to environmental issues
2	Our company is interested in supporting environmental causes	2	In our company, employees are concerned about acting in environmentally friendly ways
3	Our company believes it is important to protect the environment	3	In our company, employees try to minimise harm to the environment
4	Our company is concerned with becoming more environmentally friendly	4	In our company, employees care about the environment

Table 2.: Summary of the Green Work Climate study

Author	**Year**	**Title**	**Role**	**Country**
Norton, T. A., Zacher, H., & Ashkanasy, N. M.	2014	Organisational sustainability policies and employee green behaviour: The mediating role of work climate perceptions	Mediating	Australia
Dumont, J., Shen, J. and Deng, X	2016	Effects of green HRM practices on employee workplace green behavior: the role of psychological green climate and employee green values	Mediating	Australia
Zientara, P., & Zamojska, A	2016	Green organizational climates and employee pro-environmental behaviour in the hotel industry	Mediating	Poland
Zhou, S., Zhang, D., Lyu, C., & Zhang, H	2018	Does Seeing “Mind Acts Upon Mind” Affect Green Psychological Climate and Green Product Development Performance? The Role of Matching Between Green Transformational Leadership and Individual Green Values	Mediating	China

Author	Year	Title	Role	Country
Tian, H., Zhang, J., & Li, J	2019	The relationship between pro-environmental attitude and employee green behavior: the role of motivational states and green work climate perceptions	Mediating	China
Hicklenton, C., Hine, D. W., & Loi, N. M	2019	Can work climate foster pro-environmental behavior inside and outside of the workplace?	Moderated mediation	Australia
Khan MAS, Jianguo D, Ali M, Saleem S & Usman M	2019	Interrelations Between Ethical Leadership, Green Psychological Climate, and Organizational Environmental Citizenship Behavior: A Moderated Mediation Model.	Mediating	China
Dahiya, R	2020	Does organisational sustainability policies affect environmental attitude of employees? The missing link of green work climate perceptions	Mediating	India
Choong, Y. O., Ng, L. P., Tee, C. W., Kuar, L. S., Teoh, S. Y., & Chen, I. C.	2020	Green work climate and pro-environmental behaviour among academics: The mediating role of harmonious environmental passion	Independent	Malaysia
Sabbir, M. M., & Taufique, K. M. R.	2021	Sustainable employee green behavior in the workplace: Integrating cognitive and non-cognitive factors in corporate environmental policy	Independent	Bangladesh
Rubel, M. R. B., Kee, D. M. H., & Rimi, N. N	2021	Green human resource management and supervisor pro-environmental behavior: The role of green work climate perceptions	Mediating	Bangladesh

Author	Year	Title	Role	Country
Bhutto, T. A., Farooq, R., Talwar, S., Awan, U., & Dhir, A	2021	Green inclusive leadership and green creativity in the tourism and hospitality sector: serial mediation of green psychological climate and work engagement	Mediating	Europe
Mouro C & Duarte AP	2021	Organisational Climate and Pro-environmental Behaviours at Work: The Mediating Role of Personal Norms	Independent	Portugal
V.N. Amrutha, & S.N. Geetha Department	2021	Linking organizational green training and voluntary workplace green behavior: Mediating role of green supporting climate and employees' green satisfaction	Mediating	India
M. Sabokro, M.M. Masud & A. Kayedian	2021	The effect of green human resources management on corporate social responsibility, green psychological climate and employees' green behavior	Mediating	Iran

5. Conclusion

This review provides a systematic way of understanding the relationship between green work climate and employee green behavior specifically across different sources of data, different research designs and analysis. Concern for green behavior at work is increasing, but the impact of important concepts like green climate and others interventions still need further discussion. It is clear that fostering employee engagement with environmental initiatives can accelerate the green strategies adopted by the firms. To further develop the environmental sustainability agenda in Malaysia, organization should infuse and enhance green work climate throughout the organization to gain sustainable performance.

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GREEN TECHNOLOGY EDUCATION IN THE INTERNATIONAL BUSINESS DIPLOMA CURRICULUM: A REVIEW AND CAREER DIRECTION IN THE GREEN TECHNOLOGY FIELD

Focus Area 1: Education Management and Research

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Abstract

Green technology education is becoming increasingly important in the International Business Diploma (DPI) curriculum to equip students with relevant knowledge and skills in the era of sustainable development. This article discusses the significance of green technology education in international business, focusing on current practices, future potential, and career directions in the green technology field. Based on literature review and student feedback, green technology education effectively raises students' awareness of environmental issues, promotes sustainable business practices, and prepares them to face global challenges in international business. Student feedback also indicates that learning about green technology positively impacts their appreciation and implementation of a green lifestyle in their daily lives. This article also lists universities and higher education institutions in Malaysia that offer courses related to green technology or sustainable development, along with career opportunities in this field. For DPI students, the green technology sector offers diverse career prospects in green supply chain management, waste management, and renewable energy utilisation—fields increasingly in demand in the global job market. With the skills they acquire, DPI students can play a vital role in managing environmentally friendly business operations and contributing to sustainable development.

Keywords: Green technology, Sustainable development, Career management

1. Introduction

Green technology education is becoming increasingly important in the International Business Diploma (DPI) curriculum to equip students with relevant knowledge and skills in the era of sustainable development (UNESCO, 2017). Environmental issues such as climate change, waste management, and energy efficiency in international business have become crucial factors in business decision-making (World Economic Forum, 2020). Therefore, integrating green technology education into the curriculum ensures students understand and can apply sustainable development principles in their careers (Zhang et al., 2020).

2. Literature Review

2.1 Waste Management and Green Technology in Sustainable Development.

Waste management and green technology are crucial to addressing the environmental crisis and sustainable development. According to the United Nations Environment Programme (UNEP, 2021), effective waste management helps reduce ecological pollution and strengthens the circular economy. In international business, global organizations increasingly prioritize carbon footprint reduction strategies and adherence to sustainable practices to maintain competitiveness worldwide (World Economic Forum, 2020).

2.2 The Impact of Green Technology on Sustainable Business Practices.

Green technology is not merely a concept but necessary to ensure sustainable business practices. Companies that adopt green technology gain a competitive advantage by using renewable energy sources, reducing industrial waste, and complying with global environmental standards (Zhang et al., 2020). Studies indicate that companies implementing green technology improve operational efficiency and gain customer and investor trust in the long term (Karmakar et al., 2010).

2.3 The Role of Education in Empowering Green Technology.

Education is crucial in increasing awareness and enhancing graduates' employability in green technology. According to UNESCO (2017), higher education institutions should emphasize education for sustainable development in their curricula to ensure students understand the importance of green technology in global business. Courses such as Green Technology Compliance have positively impacted students' appreciation and practice of green technology (Meher et al., 2004)

2.4 Challenges and Opportunities in Green Technology Careers.

The demand for a workforce in the green technology sector continues to rise. Karmakar et al. (2010) reported that professionals in this field must possess technical skills in renewable energy management, the circular economy, and compliance with environmental regulations. However, the main challenge faced is the shortage of qualified personnel in this sector, highlighting the need to strengthen education and training in green technology (World Economic Forum, 2021).

2.5 The Future of Green Technology in International Business.

The Role of E-Learning in Promoting Green Innovation and Technology E-learning has emerged as a pivotal tool in advancing green innovation and technology within educational institutions. A recent study highlights that e-learning platforms facilitate disseminating knowledge related to green practices, thereby enhancing green management practices in universities (Prakoso et al., 2024). This integration supports sustainable education and prepares students to implement green technologies effectively in their future careers.

3. Student Feedback on Green Technology Learning

3.1 Impact on Appreciation

According to feedback from students of the International Business Diploma Program at Politeknik Melaka, Session 1 2023/2024, learning about green technology has increased their awareness of the importance of environmental sustainability. One student stated, "I am now more aware of the impact of human activities on the environment and how I can reduce my carbon footprint." (Nisa, 2023). Another student added, "I now value natural resources more and strive to reduce waste in my daily life." (Zulaikha, 2023).

3.2 Implementation of a Green Lifestyle

Green technology education has also encouraged students to adopt and improve green lifestyles. For example, a student running a food business reported that he now collects used cooking oil from his business to sell to recycling agents, reducing the discharge of oil into drains or waste disposal sites (Ammar, 2023). Another student shared, "I now bring a reusable cloth bag every time I go shopping and avoid using plastic straws." (Pavatarini, 2023).

Based on student feedback and green technology education among DPI students at Politeknik Melaka, this session has increased their awareness of sustainable practices. They are now more conscious of the importance of environmental preservation. This highlights the significance of green technology education in shaping responsible individuals who contribute to sustainable development.

4. Entry Requirements for the Green Technology Field for DPI Students

To ensure the continuity of learning in green technology, International Business Diploma (DPI) students interested in pursuing higher education have various options at both public and private higher education institutions. The table below lists several institutions that offer programs related to green technology and sustainable development:

Table 1: List of Higher Education Institutions Offering Programs Related to Green Technology.

Institution Name	Program Name	Minimun Qualification	Program Focus
Universiti Malaya (UM)	Bachelor of Environmental Science	CGPA minimum 3.00	Green logistics management, carbon footprint reduction inlogistics operations
Universiti Putra Malaysia (UPM)	Bachelor of Green Technology	CGPA minimum 2.75	Renewable energy use in logistics operations
Universiti Kebangsaan Malaysia (UKM)	Bachelor of Environmental Engineering	CGPA minimum 2.75	Waste management and green technology in logistics operations
Universiti Teknologi Malaysia (UTM)	Bachelor of Sustainable Energy Engineering	CGPA minimum 2.75	Renewable energy use in logistics operations

Institution Name	Program Name	Minimun Qualification	Program Focus
Universiti Sains Malaysia (USM)	Bachelor of Science in Sustainable Development	CGPA minimum 2.75	Green supply chain management and waste reduction in logistics operations
Universiti Teknologi MARA (UiTM)	Master of Environmental Management	CGPA minimum 2.50	Green logistics management and the use of green technology in logistics operations
Universiti Tun Hussein Onn Malaysia (UTHM)	Bachelor of Sustainable Energy Engineering	CGPA minimum 2.75	Renewable energy use in logistics operations
Universiti Malaysia Sabah (UMS)	Bachelor of Environmental Science	CGPA minimum 2.75	Green logistics management and carbon footprint reduction in logistics operations
Universiti Malaysia Sarawak (UNIMAS)	Bachelor of Science in Sustainable Development	CGPA minimum 2.75	Green supply chain management and waste reduction in logistics operations
Universiti Tenaga Nasional (UNITEN)	Bachelor of Energy Engineering	CGPA minimum 2.75	Green energy technology and energy efficiency
Universiti Kuala Lumpur (UniKL)	Bachelor of Environmental Engineering Technology	CGPA minimum 2.75	Green technology and innovation in business

The listing of these institutions indicates a clear pathway for DPI students to further their studies in green technology and sustainable development. Therefore, to ensure that DPI graduates are prepared to enter the rapidly growing green industry, courses such as Green Technology Compliance should be maintained in the DPI curriculum as a strategic step to enhance graduates' competitiveness in the global job market.

5. Career Pathways in the Green Technology Sector

Upon completing the International Business Diploma, students who further their green technology or sustainable development studies have broad and promising career prospects. This field is rapidly expanding in line with the increasing global awareness of sustainability and environmental preservation. Below are some relevant career fields.

5.1 Green Supply Chain Management

Graduates can work as green supply chain managers responsible for ensuring that logistics operations and product distribution are conducted sustainably and by sustainability principles—for example, companies Sime Darby and Tesco Malaysia.

5.2 Green Technology Specialist

Graduates can become specialists in green technology, focusing on managing renewable energy usage and implementing green technologies in business operations. Examples of these companies are Tenaga Nasional Berhad (TNB) and Sime Darby Energy.

5.3 Environmental Analyst

Graduates can work as environmental analysts who assess the environmental impact of business projects and recommend improvement measures to reduce adverse effects on ecosystems. Examples of companies are the Department of Environment (DOE) and WWF Malaysia.

5.4 Sustainable Development Project Manager

Graduates can become sustainable development project managers responsible for planning and implementing business projects prioritising environmental ustainability. Examples of these companies are GreenTech Malaysia and Sime Darby Plantation.

5.5 Waste Management Specialist

Graduates can work as waste management specialists who handle industrial waste and ensure compliance with environmental regulations, such as those of companies such as Alam Flora and Cenviro.

6. Market Needs and Demand in the Green Technology Sector

According to a study by Zhang et al. (2020), the global demand for a workforce in the green technology sector has increased by an average of 15% annually. In Malaysia, the demand for green technology experts is expected to rise by 20% by 2030 (World Economic Forum, 2021). This growth is driven by increasing awareness of climate change and the need to reduce the carbon footprint in the industrial sector.

7. Conclusion

Integrating green technology education into the International Business Diploma curriculum is essential to ensure that graduates are equipped with the knowledge and skills relevant to the era of sustainable development. By incorporating green technology modules, using green technology in the learning process, and close collaboration with industry, this program helps students increase their awareness of environmental issues. It promotes business practices based on sustainability principles.

Student feedback indicates that learning about green technology has positively impacted their daily appreciation and adoption of a sustainable lifestyle. Career opportunities in green technology fields—such as supply chain management, green technology, and waste management—offer strong and competitive prospects in the global job market. Therefore, the emphasis on green technology education must continue to be strengthened to ensure that future professionals can play a key role in managing sustainable business operations and contributing to sustainable development.

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BIDANG TUMPUAN 2

PENGURUSAN TENAGA DAN PERUBAHAN IKLIM

Kajian Tahap Kefahaman Dan Kesedaran Pelajar Politeknik Jeli Kelantan Mengenai 'Sustainable Development Goals' Dalam Konteks Teknologi Hijau

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Abstrak

Kajian ini bertujuan untuk mengenal pasti tahap kefahaman dan kesedaran pelajar Politeknik Jeli Kelantan terhadap Matlamat Pembangunan Lestari (Sustainable Development Goals - SDGs) dalam konteks teknologi hijau. Penyelidikan ini menggunakan pendekatan kuantitatif dengan pengedaran borang soal selidik kepada 100 orang responde yang dipilih secara rawak . Respondan terdiri daripada pelajar Program Diploma Agroternologi dan Diploma teknologi akuakultur Jabatan Agro dan Bio-Industri Politeknik jeli Kelantan. Hasil kajian mendapati bahawa secara keseluruhannya, tahap kefahaman pelajar mengenai SDGs dan teknologi hijau berada pada tahap sederhana, manakala tahap kesedaran terhadap kepentingan teknologi hijau dalam merealisasikan SDGs menunjukkan kecenderungan yang tinggi. Kajian turut mengenal pasti faktor-faktor yang mempengaruhi kefahaman dan kesedaran pelajar, antaranya pendedahan akademik, program kesedaran di kampus, serta penggunaan media sosial. Implikasi kajian ini dapat membantu pihak pengurusan politeknik terutamanya pihak Unit Pengurusan Teknologi Hijau PJK dalam merancang dan melaksanakan program atau inisiatif yang lebih efektif dalam meningkatkan kefahaman dan kesedaran pelajar tentang SDGs dan teknologi hijau sebagai persediaan menghadapi cabaran kelestarian pada masa hadapan.

Kata kunci: SDG, Matlamat Pembangunan Lestari, Teknologi Hijau

1.0 Pengenalan

Pembangunan lestari kini menjadi keutamaan global dalam menangani cabaran alam sekitar, ekonomi, dan sosial. Kesedaran mengenai Sustainable Development Goals (SDGs) semakin meningkat dalam kalangan masyarakat dunia, termasuk di Malaysia. Bagi memastikan pencapaian SDGs, teknologi hijau dianggap sebagai salah satu pendekatan kritikal yang mampu membantu masyarakat untuk hidup secara lestari dengan mengurangkan impak negatif terhadap alam sekitar. Institusi pendidikan seperti politeknik memainkan peranan penting dalam mempromosikan kesedaran dan kefahaman terhadap isu-isu kelestarian, khususnya melalui pengintegrasian teknologi hijau dalam aktiviti pembelajaran dan amalan seharian pelajar.

Politeknik Jeli, Kelantan sebagai institusi pengajian tinggi teknikal bertanggungjawab menyediakan pelajar bukan sahaja dengan kemahiran teknikal tetapi juga dengan kesedaran tentang kepentingan kelestarian alam sekitar. Namun, tahap kefahaman dan kesedaran pelajar mengenai teknologi hijau serta hubungan

teknologi tersebut dengan matlamat pembangunan lestari (SDGs) masih belum dikaji secara mendalam di institusi tersebut. Oleh itu, kajian ini bertujuan untuk mengisi jurang tersebut dengan mengukur tahap kefahaman dan kesedaran pelajar Politeknik Jeli mengenai SDGs dalam konteks teknologi hijau, sekaligus mengenal pasti sejauh mana pelajar memahami konsep-konsep utama serta kepentingan teknologi hijau dalam menyokong agenda kelestarian.

Dapatan daripada kajian ini dijangka dapat membantu pihak pentadbiran politeknik dalam merangka program pendidikan dan kesedaran yang lebih efektif, seterusnya menyumbang kepada pencapaian matlamat pembangunan lestari di peringkat kampus dan masyarakat.

1.1 Objektif kajian:

1.1.1 Mengukur tahap kefahaman pelajar terhadap SDGs.

1.1.2 Mengenal pasti tahap kesedaran pelajar terhadap teknologi hijau dalam konteks SDGs.

2.0 Sorotan literasi

Kajian literatur untuk penyelidikan ini merangkumi pemahaman tentang Sustainable Development Goals (SDGs) dalam konteks teknologi hijau. Kajian terdahulu menunjukkan bahawa pemahaman dan kesedaran mengenai SDGs dan teknologi hijau amat penting dalam memastikan kelestarian persekitaran kampus. Kajian oleh Azlan dan Norhayati (2020) mendapati bahawa kesedaran tentang teknologi hijau dalam kalangan pelajar mempengaruhi tingkah laku lestari mereka secara signifikan, khususnya dalam amalan penggunaan tenaga secara cekap dan pengurusan sisa. Kajian ini turut menegaskan bahawa latihan serta pendedahan berterusan diperlukan untuk mengekalkan sikap positif pelajar terhadap teknologi hijau.

Menurut laporan Global Sustainability Education (2021), pendidikan mengenai SDGs harus disepadukan dalam kurikulum secara menyeluruh supaya pelajar dapat memahami peranan mereka dalam mencapai matlamat pembangunan lestari ini. Tambahan pula, kajian oleh Smith dan Ali (2021) menekankan bahawa pemahaman mendalam tentang isu kelestarian alam sekitar dapat meningkatkan motivasi pelajar untuk melibatkan diri secara aktif dalam inisiatif lestari.

Selain itu, laporan dari Kementerian Alam Sekitar dan Air (2021) menegaskan pentingnya penglibatan institusi pendidikan dalam mendidik generasi muda tentang kepentingan amalan lestari melalui teknologi hijau sebagai satu langkah strategik bagi memenuhi SDGs.

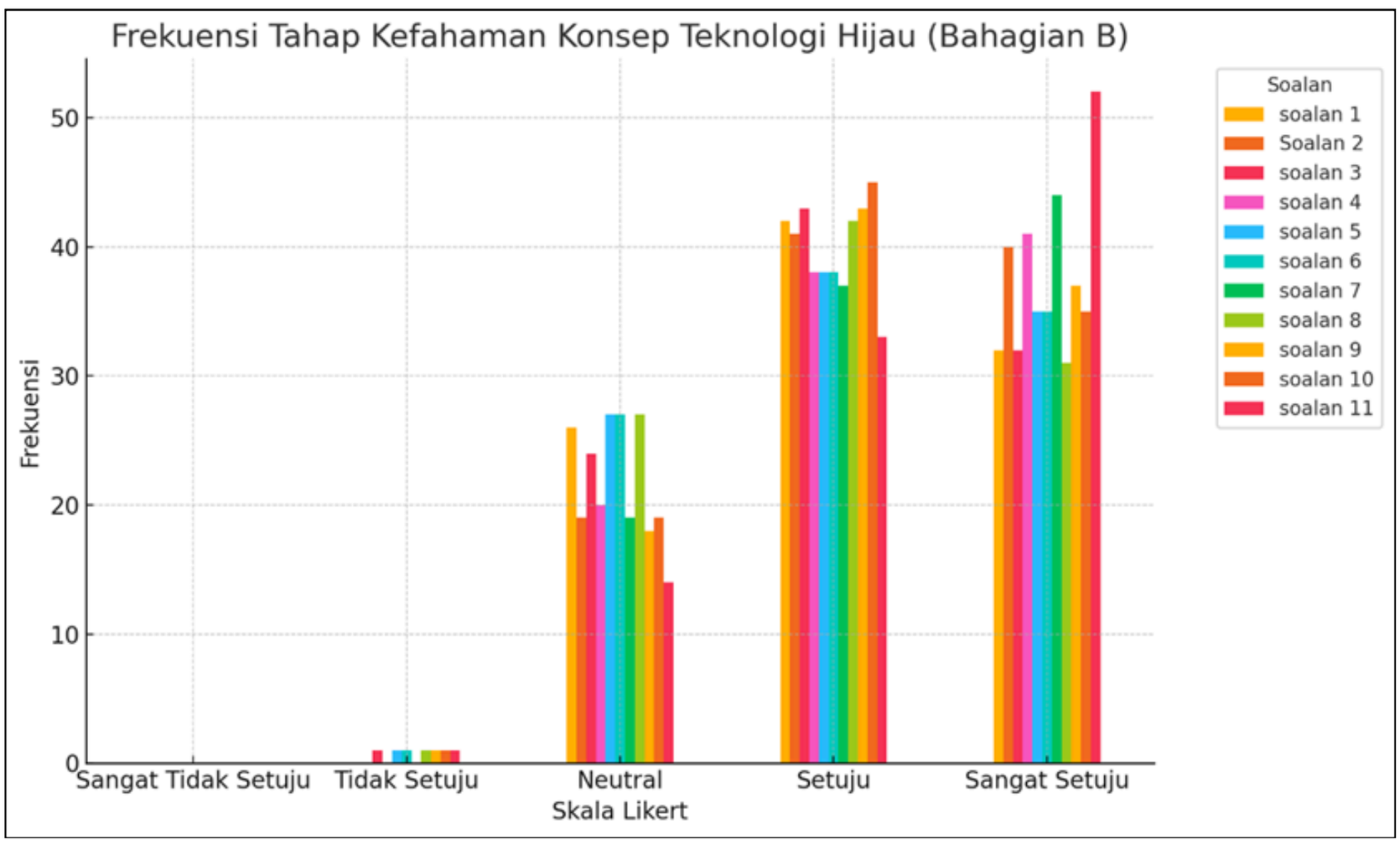
Secara keseluruhan, literatur ini mengukuhkan lagi keperluan memahami hubungan antara kefahaman teknologi hijau, kesedaran pematuhan, sikap terhadap amalan hijau, dan pemahaman SDGs untuk memastikan generasi muda dapat bertindak sebagai agen perubahan ke arah pembangunan lestari.

3.0 Metodologi

Kajian ini menggunakan pendekatan kuantitatif dengan kaedah soal selidik. Soal selidik terdiri daripada lima bahagian utama:
Bahagian A: Maklumat demografi.
Bahagian B: Tahap kefahaman konsep teknologi hijau.
Bahagian C: Kesedaran terhadap pematuhan teknologi hijau.
Bahagian D: Sikap terhadap amalan hijau di kampus.
Bahagian E: Pemahaman tentang SDGs.

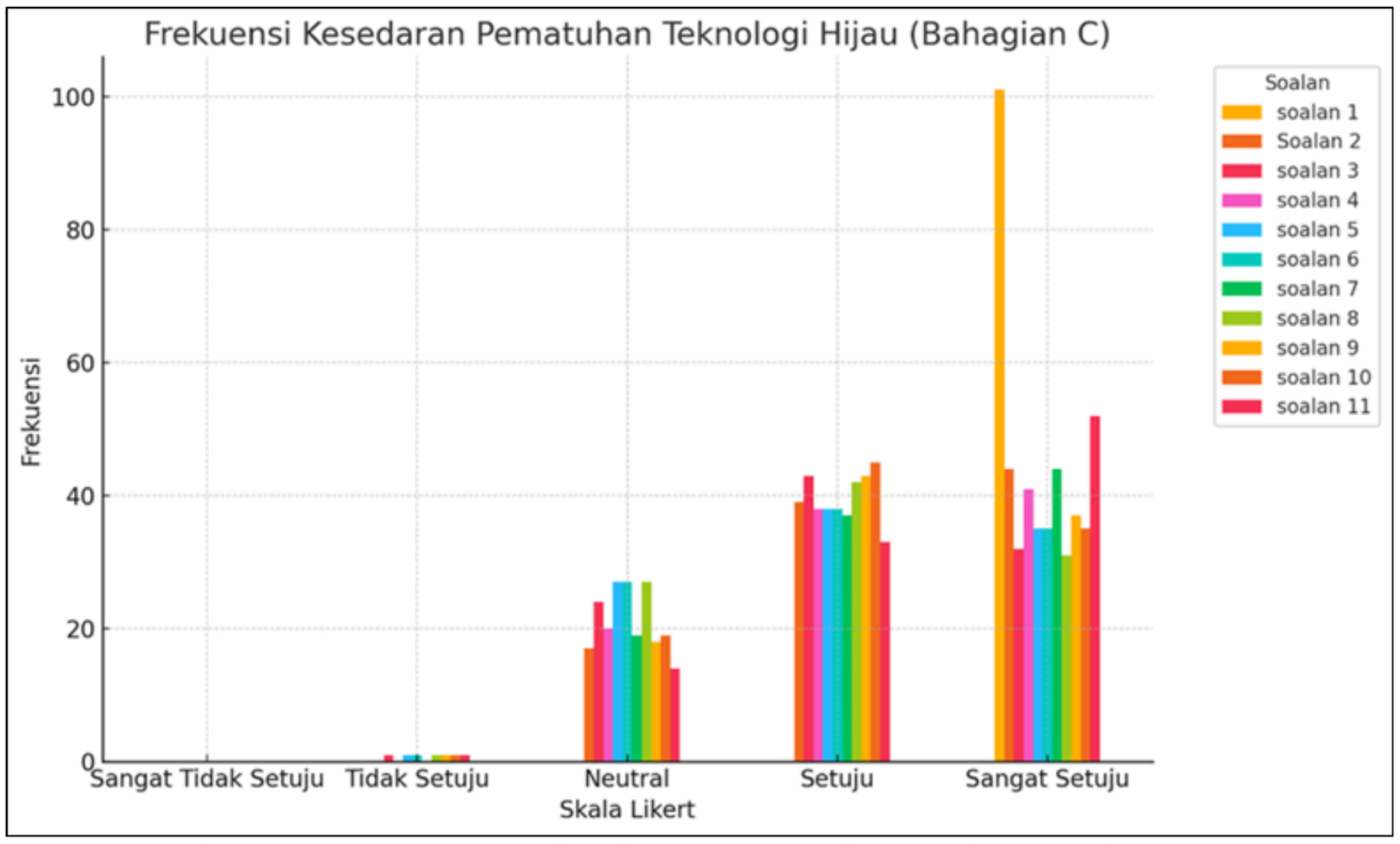
4.0 Keputusan Dan Perbincangan

4.1 Analisis Frekuensi



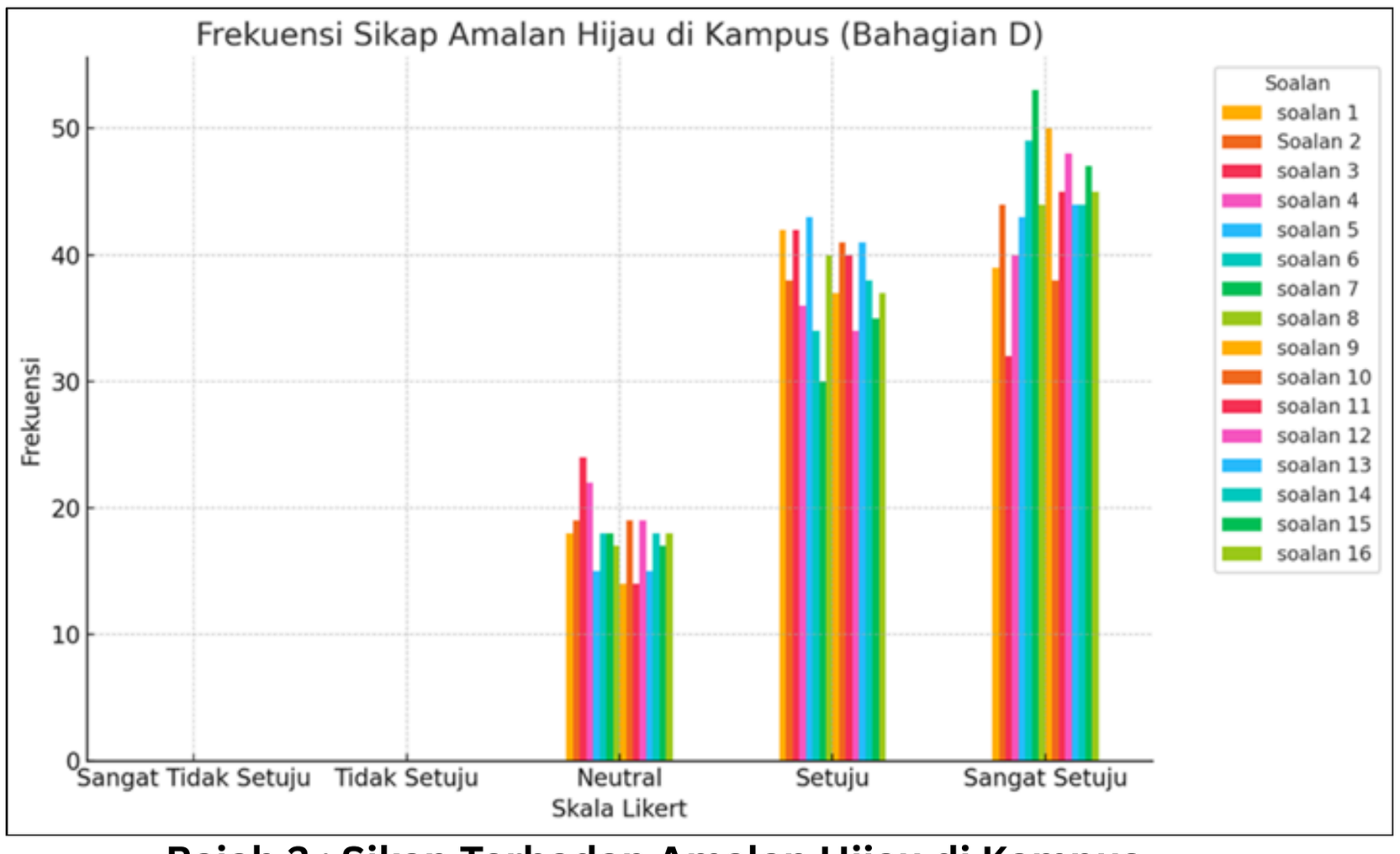
Rajah 1: Tahap Kefahaman Konsep Teknologi Hijau

Berdasarkan frekuensi Rajah 1, kebanyakan responden menunjukkan tahap kefahaman yang tinggi terhadap konsep teknologi hijau. Majoriti memilih jawapan "Setuju" dan "Sangat Setuju," dengan hanya sebilangan kecil responden bersikap neutral atau tidak setuju. Ini jelas memperlihatkan bahawa tahap kefahaman pelajar terhadap konsep teknologi hijau secara amnya adalah sangat baik.



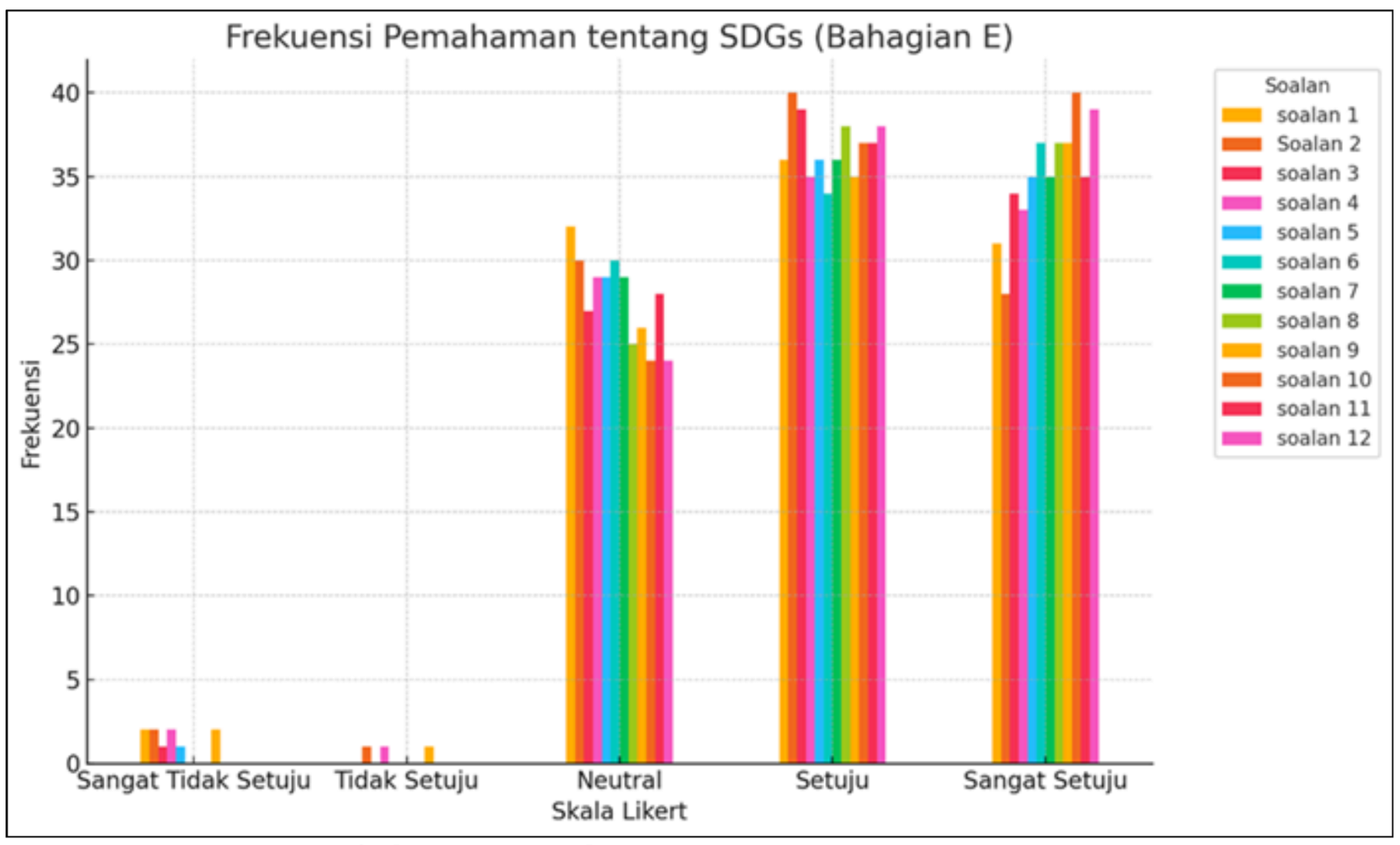
Rajah 2: Kesedaran Terhadap Pematuhan Teknologi Hijau

Analisis frekuensi bagi Rajah 2 menunjukkan tahap kesedaran pelajar yang sangat tinggi. Dimana, soalan 1 merekodkan frekuensi "Sangat Setuju" yang jauh lebih tinggi berbanding soalan-soalan lain, menunjukkan pelajar sepenuhnya sedar terhadap aspek tersebut. Soalan-soalan lain turut mencatatkan frekuensi tinggi bagi kategori "Setuju" dan "Sangat Setuju," menunjukkan tahap kesedaran yang konsisten tinggi dalam kalangan responden.



Rajah 3 : Sikap Terhadap Amalan Hijau di Kampus

Berdasarkan analisis frekuensi rajah 3, pelajar menunjukkan sikap yang sangat positif terhadap amalan hijau di kampus, dengan majoriti responden memilih jawapan "Setuju" dan "Sangat Setuju." Skor bagi kategori ini adalah konsisten tinggi bagi kesemua 16 soalan, menunjukkan sikap positif yang kukuh terhadap pelaksanaan amalan kelestarian di kampus.



Rajah 4: Pemahaman tentang SDGs

Analisis frekuensi Rajah 4 menunjukkan pemahaman pelajar tentang SDGs berada pada tahap sederhana tinggi hingga tinggi. Sebahagian besar responden memilih jawapan "Setuju" dan "Sangat Setuju," walaupun terdapat sebilangan responden yang bersikap neutral. Ini menggambarkan terdapatnya ruang untuk memperbaiki pemahaman dalam aspek tertentu tentang SDGs, khususnya pada beberapa item yang mencatatkan sedikit peningkatan pada jawapan "Neutral" berbanding bahagian-bahagian lain.

Jadual 1 : Analisis frekuensi bagi setiap bahagian

Frekuensi Analisis Tahap Kefahaman dan Kesedaran				
Tahap	Bahagian B	Bahagian C	Bahagian D	Bahagian E
Rendah (1-2)	0	0	0	0
Sederhana Rendah (2-3)	0	0	0	0
Sederhana Tinggi (3-4)	0	0	0	3
Tinggi (4-5)	11	11	16	9

Jadual 1 menunjukkan Analisis frekuensi bagi setiap bahagian yang menilai tahap kefahaman pelajar terhadap konsep teknologi hijau. Analisa menunjukkan bahawa kesemua 11 soalan (100%) berada dalam Bahagian B berada pada tahap tinggi (4-5), mencerminkan kefahaman yang sangat baik dalam kalangan responden. Bahagian C, berkaitan kesedaran terhadap pematuhan teknologi hijau, juga menunjukkan keputusan cemerlang dengan semua 11 soalan (100%) berada dalam kategori tinggi (4-5), membuktikan pelajar mempunyai tahap kesedaran yang tinggi terhadap pematuhan teknologi hijau.

Begitu juga dalam Bahagian D, iaitu sikap terhadap amalan hijau di kampus, kesemua 16 soalan (100%) turut berada dalam kategori tinggi (4-5), menggambarkan sikap positif yang amat baik terhadap amalan kelestarian. Bagaimanapun, Bahagian E mengenai pemahaman tentang Sustainable Development Goals (SDGs) mencatat keputusan sedikit berbeza, dengan 9 daripada 12 soalan (75%) berada dalam kategori tinggi (4-5), manakala 3 soalan (25%) berada dalam kategori sederhana tinggi (3-4). Ini mencadangkan bahawa masih terdapat ruang untuk peningkatan dalam beberapa aspek spesifik berkaitan pemahaman tentang SDGs dalam kalangan pelajar.

Berdasarkan analisis, ia menunjukkan tahap kefahaman, kesedaran, dan sikap pelajar terhadap teknologi hijau adalah amat positif, manakala pemahaman terhadap SDGs secara amnya positif tetapi masih mempunyai ruang untuk dipertingkatkan.

4.2 Analisis Diskriptif Statistik

Jadual 2: Tahap kefahaman pelajar mengenai Teknologi Hijau

Soalan	mean	std	min	max
soalan 1	4.04	0.79	2.0	5.0
soalan 2	4.19	0.77	2.0	5.0
soalan 3	4.06	0.77	2.0	5.0
soalan 4	4.16	0.85	1.0	5.0
soalan 5	4.06	0.81	2.0	5.0
soalan 6	4.06	0.81	2.0	5.0
soalan 7	4.25	0.75	3.0	5.0
soalan 8	4.02	0.79	2.0	5.0
soalan 9	4.16	0.76	2.0	5.0
soalan 10	4.13	0.76	2.0	5.0
soalan 11	4.35	0.77	2.0	5.0

Berdasarkan jadual 2, dapatan kajian menunjukkan bahawa kefahaman pelajar terhadap konsep teknologi hijau adalah tinggi, dengan purata min setiap soalan berada dalam julat antara 4.02 hingga 4.35 pada skala 1 hingga 5. Tahap kefahaman tertinggi direkodkan pada soalan 11 dimana mean = 4.35, std = 0.77, yang membuktikan pelajar sangat jelas mengenai konsep tersebut. Walaupun nilai terendah dicatatkan pada soalan 8 dengan purata min sebanyak 4.02, walaubagaimanapon,skor ini masih lagi berada dalam kategori tinggi. Oleh itu , Secara keseluruhannya pelajar mempunyai kefahaman yang kukuh terhadap konsep teknologi hijau.

Jadual 3: Tahap kesedaran pelajar terhadap Pematuhan Teknologi Hijau

Soalan	mean	std	min	max
soalan 1	5.0	0.0	5.0	5.0
soalan 2	4.27	0.74	3.0	5.0
soalan 3	4.06	0.77	2.0	5.0
soalan 4	4.16	0.85	1.0	5.0
soalan 5	4.06	0.81	2.0	5.0
soalan 6	4.06	0.81	2.0	5.0
soalan 7	4.25	0.75	3.0	5.0
soalan 8	4.02	0.79	2.0	5.0
soalan 9	4.16	0.76	2.0	5.0
soalan 10	4.13	0.76	2.0	5.0
soalan 11	4.35	0.77	2.0	5.0

Jadual 3 iaitu Kesedaran Terhadap Pematuhan Teknologi Hijau, menunjukkan tahap kesedaran pelajar berada pada tahap yang amat tinggi dengan kesemua item mencatatkan nilai purata melebihi 4.0. Kita boleh lihat, soalan pertama mencatatkan skor (mean = 5.0, std = 0.0), menggambarkan kesedaran penuh responden mengenai perkara yang dinilai dalam soalan tersebut. Kebanyakan soalan lain turut menunjukkan skor min yang konsisten tinggi, berada dalam julat antara 4.02 hingga 4.35, menjelaskan lagi bahawa pelajar memiliki tahap kesedaran yang tinggi secara keseluruhannya terhadap pematuhan teknologi hijau.

Jadual 4: Sikap pelajar terhadap Amalan Hijau di kampus

Soalan	mean	std	min	max
soalan 1	4.19	0.76	2.0	5.0
soalan 2	4.25	0.75	3.0	5.0
soalan 3	4.02	0.82	2.0	5.0
soalan 4	4.14	0.83	2.0	5.0
soalan 5	4.28	0.71	3.0	5.0
soalan 6	4.31	0.76	3.0	5.0
soalan 7	4.35	0.77	3.0	5.0
soalan 8	4.27	0.73	3.0	5.0
soalan 9	4.36	0.72	3.0	5.0
soalan 10	4.13	0.82	2.0	5.0
soalan 11	4.29	0.74	2.0	5.0
soalan 12	4.29	0.77	3.0	5.0
soalan 13	4.29	0.71	3.0	5.0
soalan 14	4.26	0.75	3.0	5.0
soalan 15	4.28	0.78	2.0	5.0
soalan 16	4.25	0.78	2.0	5.0

Jadual 4 Analisa Diskriptif Statistik mengenai Sikap Terhadap Amalan Hijau di Kampus. Analisa menunjukkan bahawa pelajar mempunyai sikap yang sangat positif terhadap amalan hijau, dengan purata keseluruhan soalan berada pada tahap tinggi (antara 4.02 hingga 4.36) manakala Soalan 9 mencatatkan skor tertinggi (mean = 4.36, std = 0.72), memperlihatkan sikap yang amat positif pelajar terhadap amalan hijau. Secara keseluruhannya, sikap positif ini adalah konsisten merentasi semua item dalam soal selidik.

Jadual 5: Pemahaman tentang SDGs

Soalan	mean	std	min	max
soalan 1	3.93	0.9	1.0	5.0
soalan 2	3.9	0.89	1.0	5.0
soalan 3	4.04	0.84	1.0	5.0
soalan 4	3.96	0.92	1.0	5.0
soalan 5	4.03	0.85	1.0	5.0
soalan 6	4.07	0.82	3.0	5.0
soalan 7	4.06	0.8	3.0	5.0
soalan 8	4.12	0.78	3.0	5.0
soalan 9	4.03	0.92	1.0	5.0
soalan 10	4.16	0.78	3.0	5.0
soalan 11	4.07	0.79	3.0	5.0
soalan 12	4.15	0.78	3.0	5.0

Jadual 5 menunjukkan Analisa Diskriptif mengenai pemahaman tentang Sustainable Development Goals (SDGs).keputusan menunjukkan tahap pemahaman pelajar berada pada tahap sederhana tinggi, dengan purata min antara 3.90 hingga 4.16. Soalan 10 mencatatkan purata tertinggi (mean = 4.16, std = 0.78), mencerminkan pemahaman pelajar yang baik terhadap elemen khusus dalam SDGs yang dinilai. Walaupun soalan 2 mencatatkan skor terendah (mean = 3.90), nilai tersebut masih berada dalam kategori sederhana tinggi, menunjukkan pemahaman pelajar secara umumnya baik, namun masih terdapat ruang untuk peningkatan dalam aspek tertentu.

Jadual 6: Analisa Deskriptif keseluruhan

Bahagian	Perkara yang Diukur	Nilai Min	Sisihan Piawai	Tahap
Jadual 1	Kefahaman Konsep Teknologi Hijau	4.02 - 4.35	0.77	Tinggi
Jadual 2	Kesedaran Terhadap Pematuhan Teknologi Hijau	4.02 - 5.00	0.00 - 0.78	Sangat Tinggi
Jadual 3	Sikap Terhadap Amalan Hijau di Kampus	4.02 - 4.36	0.72	Tinggi
Jadual 4	Pemahaman tentang SDGs	3.90 - 4.16	0.78	Sederhana Tinggi - Tinggi

Secara keseluruhannya, kajian ini menunjukkan bahawa tahap kefahaman, kesedaran, sikap dan pemahaman pelajar Politeknik Jeli Kelantan terhadap konsep teknologi hijau dan Sustainable Development Goals (SDGs) berada pada tahap yang baik hingga sangat baik. Bahagian B mencatatkan tahap kefahaman yang tinggi terhadap teknologi hijau, dengan nilai min antara 4.02 hingga 4.35. Sisihan piawai yang rendah (contohnya 0.77 pada skor tertinggi) menggambarkan konsistensi jawapan responden yang baik.

Dalam Bahagian C pula, tahap kesedaran pelajar terhadap pematuhan teknologi hijau turut tinggi, malah salah satu item mencapai skor sempurna (mean = 5.0, std = 0.0). Ini mencerminkan kesedaran tinggi yang kukuh dalam kalangan pelajar mengenai aspek-aspek teknologi hijau.

Bahagian D, mengenai sikap terhadap amalan hijau di kampus, juga mencatatkan skor yang konsisten tinggi (antara 4.02 hingga 4.36), dengan sisihan piawai yang rendah (contohnya 0.72 pada soalan tertinggi), menunjukkan sikap positif yang stabil di kalangan responden terhadap usaha kelestarian di kampus.

Walau bagaimanapun, dalam Bahagian E, walaupun tahap pemahaman terhadap SDGs berada dalam kategori sederhana tinggi hingga tinggi (antara 3.90 hingga 4.16), sisihan piawai yang sedikit tinggi (contohnya 0.78 pada item tertinggi) menunjukkan wujudnya variasi dalam pemahaman pelajar, mencadangkan adanya ruang untuk penambahbaikan terutamanya dalam aspek spesifik berkaitan SDGs. Secara keseluruhan, kajian ini memberikan gambaran positif mengenai kesiapsiagaan pelajar Politeknik Jeli Kelantan dalam konteks pembangunan lestari dan teknologi hijau, tetapi masih memerlukan tindakan susulan melalui program pendidikan atau kesedaran khusus bagi mengukuhkan lagi kefahaman terhadap SDGs secara menyeluruh.

4.3 Perbincangan

Berdasarkan hasil analisis data, kajian ini mendapati bahawa tahap kefahaman dan kesedaran pelajar Politeknik Jeli Kelantan terhadap Matlamat Pembangunan Lestari (SDGs) dalam konteks teknologi hijau adalah secara amnya positif. Secara khususnya, pelajar menunjukkan tahap kefahaman yang tinggi terhadap konsep teknologi hijau dengan skor purata antara 4.02 hingga 4.35. Ini mencerminkan keberkesanan pendedahan akademik dan program-program kampus yang telah dijalankan dalam mendidik pelajar mengenai teknologi hijau.

Tahap kesedaran pelajar terhadap pematuhan teknologi hijau juga amat menggalakkan dengan purata skor keseluruhan tinggi (melebihi 4.0), yang mana salah satu item mencatat skor sempurna (mean=5.0). Dapatan ini jelas menunjukkan kesedaran pelajar terhadap pentingnya teknologi hijau untuk mencapai kelestarian adalah sangat baik, sekaligus mampu menyokong agenda pembangunan lestari dalam kehidupan kampus mereka.

Selain itu, sikap pelajar terhadap amalan hijau di kampus juga mencatatkan nilai positif yang tinggi secara konsisten merentasi semua item yang dikaji (antara 4.02 hingga 4.36). Ini membuktikan bahawa pelajar bukan sahaja memahami, tetapi juga bersikap positif terhadap usaha dan inisiatif kelestarian yang dijalankan di kampus.

Walau bagaimanapun, pemahaman mengenai SDGs secara keseluruhannya berada pada tahap sederhana tinggi dengan skor antara 3.90 hingga 4.16. Variasi skor yang agak tinggi dalam aspek ini mencadangkan bahawa masih ada ruang untuk memperbaiki aspek tertentu dalam pendidikan mengenai SDGs, terutamanya yang melibatkan pemahaman mendalam terhadap matlamat tertentu SDGs.

Secara implikasi, dapatan kajian ini boleh dijadikan panduan untuk pihak pengurusan politeknik merancang dan melaksanakan program atau kempen kesedaran yang lebih strategik dan berkesan bagi meningkatkan lagi kefahaman dan kesedaran pelajar terhadap SDGs dan teknologi hijau.

5.0 Kesimpulan

Kesimpulannya, kajian ini telah berjaya menunjukkan bahawa pelajar Politeknik Jeli Kelantan mempunyai tahap kefahaman, kesedaran dan sikap yang positif terhadap teknologi hijau serta matlamat pembangunan lestari (SDGs). Namun demikian, pihak pentadbiran politeknik perlu terus berusaha meningkatkan pemahaman mendalam terhadap matlamat-matlamat SDGs melalui pendekatan akademik dan bukan akademik secara berterusan, bagi memastikan pelajar bersedia menghadapi cabaran global kelestarian pada masa depan.

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BIDANG TUMPUAN 4

PENGURUSAN SISA

Production of Paper Bag from Banana Fronds

Focus Area 4: Waste Management

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Abstract

Plastic pollution has become a significant environmental issue worldwide due to its non-biodegradable nature and widespread use. The excessive reliance on plastic bags has contributed to land and marine pollution, negatively impacting ecosystems and human health. This study explores the potential of using banana fronds as an alternative raw material for paper bag production. The primary objective of this research is to design the manufacturing process, produce paper bags using banana fronds, and evaluate their durability and biodegradability compared to commercially available paper bags. This research employs an experimental approach, focusing on two primary tests: water resistance and biodegradability. The findings indicate that commercially available paper bags exhibit superior water resistance, whereas banana frond paper bags demonstrate higher biodegradability. Despite their lower durability, paper bags made from banana fronds provide a sustainable and eco-friendly alternative, particularly for light-duty packaging applications. This study contributes to the development of sustainable packaging solutions and encourages the repurposing of agricultural waste. Further improvements in material composition and processing techniques could enhance the practicality of banana frond paper bags for broader applications.

Keywords: Plastic pollution, banana fronds, biodegradability.

1.0 Introduction

Over the years, the production has increase significantly. In the year 1950, the world produced two million tons of plastic. Now plastic production around the globe is over 450 million tonnes. Mismanaged plastic which has not been recycled, incinerated, or kept in sealed landfills has become pollutant. One to two million tonnes of plastic enter our oceans yearly, affecting wildlife and ecosystems.

Plastic is one of the most enduring materials that man has created. It takes hundreds of years to degrade with some research showing that it does not even fully degrade but becomes microplastic which are tiny particles of plastic. Plastic that enters the ocean will affect the wellbeing of every life on the planet. Microplastic that are eaten by marine animals will end up in their body and tissues, entering the food chain leading to a disastrous consequence to the health of all life, humans and animals alike. With the number of plastics in our ocean increasing, plastic pollution will lead to more marine species extinction, health problems and destruction of the ecosystem.

The majority of the plastic pollution in our oceans come from littering. Items such as food wrappings, plastic bags, razors, bottles, etc have not been dispose properly which is causing them to end up in rivers, waterways and eventually reaching the ocean. Yet not all-plastic waste in the ocean comes from littering, many plastics and microplastic comes from improper manufacturing processes and 20% of ocean's plastic pollution comes from industrial fishing.

Today, plastic production and uses are at its peak, but the data shows only 10% of the plastic produce are being recycled. The rest are being incinerated which cause air pollution or end up in oceans and environment. Plastic that ends up in the ocean is harming marines' wildlife when the animals ingest them which will result in suffocation, entanglement, laceration, infections and internal injuries. Furthermore, floating plastic items in the ocean can help transport invasive species which leads to threats on the marine ecosystems and biodiversity.

Microplastics have entered the food chain and can now be found everywhere: drinking water, salt, beer and in the soil used to grow vegetables. Plastic materials are carcinogenic, it can affect the body's endocrine system, causing developmental, neurological, reproductive and immune disorders. Another health hazard is given by toxic contaminants that accumulate on the plastic's surface and are transferred into humans through seafood consumption.

Over 99% of plastic is made out of petrochemicals derived from fossil fuels, which increase the concentration of hazardous air pollutants during the extraction process. Oil and gas drilling can release lots of toxic air contaminants including benzene, carbon monoxide, ethylbenzene, hydrogen sulphide, ozone, particulate matter, sulphur dioxide, toluene, volatile organic compounds and xylene.

Microplastic is not only a threat to our ocean but also to our air. Research has shown that we can now breathe in tiny microplastic particles that are in the air through our nose and mouth, with the tiniest particles small enough to pass into our lung tissue. Worryingly, scientist have found more microplastic in homes than outdoors. Babies and children are more vulnerable to microplastic that adult, they inhale more air due to their rapid breathing patterns and respiratory system development.

A huge amount plastic waste has resulted into plastic burning. However, when plastic is heated it releases toxic chemicals such as hydrochloric acid, sulphur dioxide and dioxins into the air which cause a higher potential for illnesses such as respiratory and others.

To summarize, plastic has help humans developed new technologies and create new advancement in our daily life. However unmanaged plastic waste has given a huge effect to the environment, causing problems such as air pollution, water pollution and health concerns.

The objectives of the study are:

1. Plan the process of the paper bag creation using banana fronds.
2. Create a paper bag using banana fronds.
3. Test the durability of the paper bag created using banana fronds.

2.0 Literature Review

Plastic pollution has become one of the most critical environmental challenges of the modern era. Since the introduction of synthetic plastic in the early 20th century, global plastic production has increased dramatically. According to Jambeck et al. (2015), approximately 8 million metric tons of plastic waste enter the oceans every year, contributing to severe marine pollution. Plastics, particularly microplastics, have been found in various ecosystems, including freshwater sources, soil, and even human food chains. These materials take centuries to degrade, and in many cases, they break down into microplastics, which persist in the environment indefinitely.

The environmental consequences of plastic pollution are severe. Marine life, including fish, turtles, and seabirds, often mistake plastic debris for food, leading to ingestion and entanglement-related fatalities (Thompson et al., 2009). Furthermore, the leaching of toxic chemicals from plastics into the soil and water has been linked to various health issues in both humans and wildlife (Geyer, Jambeck, & Law, 2017). Given these alarming statistics, there is an urgent need to develop eco-friendly alternatives to plastic, particularly in the packaging industry

In response to growing environmental concerns, researchers and manufacturers have explored various sustainable packaging materials. Biodegradable alternatives such as jute, hemp, and cotton have gained attention due to their lower environmental impact (Smith & Williams, 2018). Paper-based packaging, in particular, has been widely adopted due to its biodegradability and recyclability. However, traditional paper production relies heavily on deforestation, leading to further environmental degradation.

Banana fronds have emerged as a promising alternative material for paper production. As an agricultural by-product, banana fronds are readily available and often discarded as waste. Studies have shown that banana fiber possesses high cellulose content and excellent tensile strength, making it a viable substitute for conventional wood pulp in paper manufacturing (Lee & Tan, 2020). Utilizing banana fronds in paper production not only reduces dependency on tree-based paper but also provides an effective solution for managing agricultural waste.

Banana fronds have been extensively studied for their potential in sustainable paper manufacturing. Research by Ali & Zulkifli (2020) indicates that banana fibers have a high cellulose-to-lignin ratio, which enhances their suitability for papermaking. Unlike wood pulp, which requires extensive chemical processing, banana fibers can be processed using relatively simple and environmentally friendly methods.

Moreover, banana fronds are highly biodegradable, decomposing much faster than synthetic materials. A study by Tan & Ramli (2019) found that paper made from banana fibers decomposed within 30 days under natural conditions, compared to conventional plastic, which takes hundreds of years. This rapid biodegradation makes banana frond-based paper an ideal choice for short-term packaging applications.

Several studies have investigated the feasibility of biodegradable packaging materials. Hopewell, Dvorak, & Kosior (2009) conducted a comprehensive analysis of biodegradable materials and concluded that plant-based fibers offer the most promising alternative to plastic. Their findings highlight the importance of selecting raw materials that not only reduce environmental impact but also provide sufficient durability and functionality.

Research by Chong & Ismail (2018) supports the use of banana fronds in paper production, citing their abundance, ease of processing, and high fiber strength as key advantages. Additionally, studies have shown that combining banana fibers with other plant-based materials can further enhance the quality and durability of biodegradable packaging (Lee & Nor, 2022). However, challenges remain in improving water resistance and mechanical strength, which are essential factors for commercial viability.

Despite the promising potential of banana fronds in paper production, several challenges must be addressed. One of the primary concerns is water resistance. Unlike plastic, which is inherently waterproof, paper-based materials tend to absorb moisture, reducing their durability. Studies suggest that incorporating natural resins or wax coatings could improve the water resistance of banana frond paper bags (Smith & Williams, 2018).

Another challenge lies in scalability and cost-effectiveness. While banana fronds are abundant, large-scale processing requires specialized equipment and infrastructure. Further research is needed to develop efficient production techniques that minimize costs while maintaining quality standards.

3.0 Methodology

This study adopts an experimental research design to evaluate the feasibility of banana fronds as a raw material for paper bag production. The research is divided into three main phases: the preparation and production of paper bags, testing the durability and biodegradability of the produced paper bags, and comparing the results with commercially available paper bags. The experimental approach is chosen to obtain empirical evidence regarding the material's performance in real-world applications.

3.1 The materials and equipment used in this study include:

i) Raw materials: Banana fronds (collected from banana plantations), water

ii) Equipment: Scissors, blender, fabric filter, drying trays, weighing scale, water container, stopwatch

iii) Testing tools: Measuring cylinder for water absorption test, composting environment for biodegradability test

3.2 The process of making paper bags from banana fronds follows several key steps:

i) Collection and Preparation of Raw Materials: Banana fronds are collected, cleaned, and cut into small pieces to facilitate the blending process.

ii) Pulp Formation: The cut banana fronds are blended with water to create a pulp-like mixture. Sheet Formation: The pulp is spread evenly on a fabric filter to form a thin sheet.

iii) Drying Process: The formed sheet is left to dry under the sun until it becomes a solid paper sheet.

iv) Final Assembly: The edges of the paper bag are secured using eco-friendly adhesives, completing the final product.

3.3 Two primary tests are conducted to evaluate the quality of the banana frond paper bags:

i) Water Resistance Test:

The water resistance of the paper bags is tested to determine their ability to withstand exposure to moisture. The test involves the following steps:

- A controlled amount of water is poured onto the surface of the paper bag.
- The time taken for the water to be fully absorbed by the material is recorded.
- The results of the banana frond paper bag are compared with commercially available paper bags.

3.4 Biodegradability Test

To assess the biodegradability of the banana frond paper bags, a composting experiment is conducted. The test follows these steps:

i) The paper bag samples are placed in a controlled composting environment.

ii) The weight of the samples is measured before and after exposure to decomposition conditions over a 15-day period.

iii) Visual observations are made to document physical changes in the material.

iv) The degradation rate of the banana frond paper bags is compared with that of commercially available paper bags.

3.5 Data Collection and Analysis

The data obtained from the experiments are recorded systematically. The water resistance test results are measured in terms of the time taken for complete water absorption. The biodegradability test results are analysed based on weight loss percentages and physical decomposition observations. The collected data are compared between banana frond paper bags and commercially available paper bags to determine the material's effectiveness as an alternative packaging solution.

This study ensures ethical compliance by using eco-friendly materials and minimizing waste production. The research follows sustainable practices, and all testing methods are designed to prevent harm to the environment. Additionally, the study promotes the use of biodegradable materials to support environmental conservation.

4.0 Results and Discussions

4.1 Water Resistance Test

An experiment has been carried out to test the water resistance level of the product, the test includes a paper bag that was made from banana fronds and a paper bag that was bought in the nearest store. To test the water resistance of the paper bags, the material was exposed to water and being measured using time taken for the material to absorb water. The result from the experiment is as follows:

Table 1: Water Resistance Test

Number of Tests	Banana Fronds Paper Bag(Minutes)	DIY Paper Bag (Minutes)
1	2:06	3:12
2	1:04	4:41
3	1:24	5:30
4	1:30	5:50
5	1:40	5:45
6	1:45	5:51
7	1:43	5:53
8	1:37	5:40
9	1:50	5:49
10	1:35	5:00
11	1:44	5:12
12	1:40	4:49
13	1:45	5:20
14	1:38	5:50
15	1:40	5:13

Table 2 : Water Resistance Test Average

Types of Paper Bags	Mean (Minutes)
Banana Fronds	1:42
DIY Paper Bag	5:07

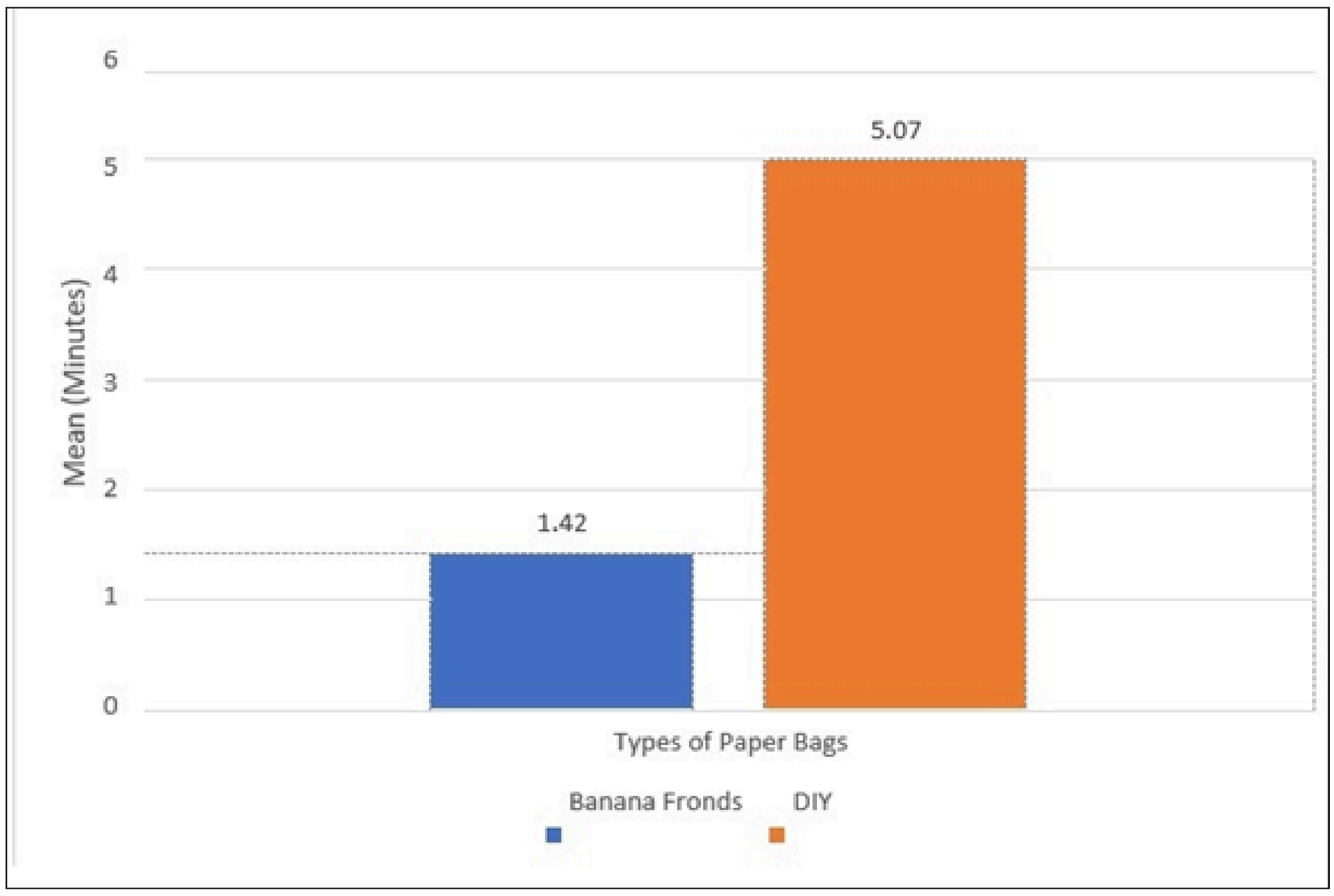

Diagram 1: Comparison for the Average Time Taken for the Material to Absorb Water

The water resistance test aimed to measure how well the banana frond paper bags could withstand moisture exposure. The experiment involved pouring a controlled amount of water onto the surface of the paper bags and recording the time taken for the material to absorb the water completely. The results of diagram 1 indicate that commercially available paper bags demonstrated superior water resistance, with an average absorption time of 5 minutes and 7 seconds. In contrast, banana frond paper bags absorbed water much more quickly, with an average time of 1 minute and 42 seconds. The significant difference in water absorption times suggests that banana frond paper bags have lower resistance to moisture, making them less suitable for packaging items exposed to humid or wet conditions.

These findings highlight a major limitation of banana frond paper bags. The high water absorption rate may be attributed to the fibrous nature of banana fronds, which lack protective coatings found in commercial paper bags. Potential improvements could involve the application of natural wax or bio-based coatings to enhance water resistance.

4.2 Biodegradability Test Results

The biodegradability test was conducted to assess how quickly the banana frond paper bags decomposed compared to commercially available paper bags. The test involved placing both types of bags in a composting environment and recording weight loss and physical changes over 15 days.

The results show that banana frond paper bags degraded at a significantly faster rate. After 15 days, the banana frond paper bags lost an average of 13 grams in weight, while commercially available paper bags only lost 1 gram. Visual observations confirmed that banana frond paper bags attracted more decomposers such as fungi and termites, leading to faster breakdown.

The superior biodegradability of banana frond paper bags is a major advantage in environmental conservation. The rapid decomposition reduces landfill waste and minimizes long-term environmental impact. However, this also indicates that these bags may have a shorter shelf life, requiring proper storage conditions to prevent premature degradation.

The results of the study provide key insights into the advantages and limitations of banana frond paper bags. The most notable findings are:

i) Water Absorption: Banana frond paper bags have a significantly lower resistance to water,making them unsuitable for packaging items that require moisture protection. However, this issue can be addressed by incorporating natural coatings

ii) Biodegradability: The rapid decomposition of banana frond paper bags demonstrates their environmental benefits. These bags are ideal for short-term use and compostable packaging applications.

iii) Structural Strength: The study also observed that banana frond paper bags could withstand up to 500 grams of weight. While this is lower than commercial paper bags, it is sufficient for lightweight packaging purposes.

iv) Potential Applications: Given their quick biodegradation rate, banana frond paper bags could be used for products that require sustainable and disposable packaging, such as grocery bags, gift wraps, and compostable food packaging.

4.3 Recommendations for Improvement

Based on the findings, several recommendations can be made to enhance the effectiveness of banana frond paper bags:

i) Improving Water Resistance: Applying biodegradable coatings, such as beeswax or cornstarch - based films, could improve water resistance without compromising biodegradability.

ii) Strengthening the Material: Incorporating other natural fibers, such as bamboo or rice straw, could enhance the durability and load-bearing capacity of the paper bags.

iii) Optimizing Production Methods: Refining the pulping and drying processes may improve the consistency and quality of the final product.

iv) Developing Multiple Sizes and Designs: Creating different sizes and shapes would increase the versatility of banana frond paper bags for various applications

The findings confirmed that while banana frond paper bags exhibit lower water resistance, they decompose significantly faster than commercially available paper bags, making them an eco-friendly alternative. Further research and material enhancements can help improve their practicality and expand their applications in sustainable packaging solutions.

5.0 Conclusion and Recommendations

5.1 Conclusion

The study successfully achieved its objectives by designing, producing, and evaluating paper bags made from banana fronds. The research confirmed that while banana frond paper bags are highly biodegradable and environmentally friendly, they exhibit lower water resistance compared to commercially available paper bags. This trade-off suggests that banana frond paper bags are best suited for applications where moisture exposure is minimal and biodegradability is a priority.

The study also revealed that banana frond paper bags could withstand up to 500 grams of weight, making them suitable for lightweight packaging applications. Their rapid decomposition rate offers a significant environmental advantage, reducing landfill waste and supporting sustainable waste management practices. Despite these benefits, further research is needed to improve the structural integrity and moisture resistance of banana frond paper bags to enhance their commercial viability.

5.2 Recommendations

Based on the study's findings, the following recommendations are proposed:

i) Enhancing Water Resistance: Future studies should explore the application of biodegradable coatings, such as natural waxes or starch-based films, to improve the water resistance of banana frond paper bags.

ii) Improving Material Strength: Incorporating other natural fibers, such as bamboo or rice straw, may enhance the mechanical strength and durability of the bags.

iii) Optimizing the Production Process: Refining the pulping and drying techniques could improve the consistency and quality of the final product, making it more competitive with commercially available paper bags.

iv) Developing Various Designs and Sizes: Producing different shapes and sizes could expand the potential applications of banana frond paper bags, increasing their appeal to consumers and businesses.

v) Long-term Degradation Studies: Conducting long-term biodegradation studies under different environmental conditions would provide more insights into the decomposition behaviour of banana frond-based paper bags.

This study contributes to the growing body of research on sustainable packaging solutions. By demonstrating the potential of banana fronds as a biodegradable alternative to plastic bags, this research encourages further exploration of agricultural waste materials in packaging applications. The findings support environmental conservation efforts by promoting waste reduction and eco-friendly product development. From an industrial perspective, the study offers valuable insights for manufacturers and policymakers seeking to transition toward sustainable packaging solutions. The potential commercialization of banana frond paper bags could create new opportunities for green businesses and reduce reliance on plastic-based materials.

5.3 Summary

In conclusion, this study has demonstrated that banana frond-based paper bags offer a promising alternative to plastic and conventional paper bags. While they excel in biodegradability, improvements are needed in water resistance and mechanical strength to enhance their usability. The study provides a foundation for future research and development in sustainable packaging materials. By implementing the recommended improvements, banana frond paper bags could play a vital role in reducing plastic waste and promoting environmental sustainability.

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DEVELOPMENT OF ECO-FRIENDLY FIRE CUBES FROM RECYCLED SHREDDED PAPER: A SUSTAINABLE APPROACH TO WASTE MANAGEMENT AND PRODUCT INNOVATION

Focus Area 4: Waste Management

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Abstract

This study explores the development of eco-friendly fire cubes using recycled shredded paper and beeswax, addressing the growing demand for sustainable fire-starting solutions. The research compares two paper textures—strip-cut and rough-torn—to evaluate their burning efficiency, ignition strength, and burn duration. Controlled tests and user feedback were conducted to assess the performance of the prototypes. Results indicate that rough-torn paper outperformed strip-cut paper, offering a longer burn duration (21 minutes vs. 19 minutes) and stronger ignition, making it more suitable for outdoor activities like camping and barbecuing. User feedback highlighted the product's ease of use, environmental benefits, and cost-effectiveness. The project aligns with Sustainable Development Goals (SDGs) by promoting responsible consumption, waste reduction, and climate action. Collaboration with CLINex Solutions ensured a sustainable supply of recycled materials, enhancing the project's feasibility. The findings demonstrate that recycled paper can be effectively repurposed into a practical, eco-friendly product, offering a viable alternative to traditional fire starters. This research underscores the potential of sustainable product development in addressing environmental challenges while meeting consumer needs.

Keywords: Eco-friendly fire cubes, Recycled paper waste, Sustainable fire starters

1. Introduction

The increasing global emphasis on environmental sustainability has driven the demand for innovative solutions that reduce waste and promote eco-friendly practices. One such innovation is the development of fire cubes from recycled paper waste, a project undertaken in collaboration with CLINex Solutions, a Bumiputera-owned company specializing in secure document disposal and waste management.

This study focuses on creating fire starter cubes using shredded paper and beeswax, aiming to provide a sustainable alternative to traditional fire starters made from non-recyclable materials. By leveraging recycled materials, this project aligns with the United Nations Sustainable Development Goals (SDGs), particularly Goal 12 (Responsible Consumption and Production) and Goal 13 (Climate Action) (United Nations, 2022).

The primary objective of this study is to evaluate the performance of fire cubes made from two different textures of shredded paper (strip-cut and rough-torn) in terms of burn duration, ignition strength, and user satisfaction. Additionally, the study aims to assess the economic viability of mass-producing these fire cubes and their potential market appeal among outdoor enthusiasts, including campers, hikers, and barbecue lovers. The collaboration with CLINex Solutions ensures a consistent supply of recycled materials and provides valuable insights into sustainable waste management practices.

2. Literature Review

The concept of sustainable waste management has gained significant attention in recent years, with numerous studies highlighting the importance of recycling and repurposing materials to reduce environmental impact. According to Smith (2020), eco-friendly fire starters made from recycled materials offer a viable alternative to traditional fire starters, which often rely on synthetic and non-recyclable components. Similarly, GreenBiz Editors (2022) emphasize the growing consumer preference for sustainable products, particularly in the outdoor activities market, where eco-conscious consumers seek products that align with their environmental values.

The use of recycled paper in product development has been widely studied, with researchers noting its environmental and economic benefits. Recycled paper not only reduces the amount of waste sent to landfills but also mitigates the negative impacts of deforestation and resource depletion (United Nations, 2022). Furthermore, the incorporation of beeswax as a natural binding agent enhances the combustibility and burn duration of fire starters, making it an ideal material for this application (NielsenIQ, 2019).

This study builds on existing research by exploring the performance of fire cubes made from two different textures of shredded paper, providing new insights into the optimal use of recycled materials for sustainable product development.

3. Methodology

The methodology for this study involves a systematic approach to product development, including material sourcing, prototype creation, and user testing. The process begins with the collection of shredded paper from CLINex Solutions and office waste, which is then soaked in melted beeswax to create fire cube prototypes. Two textures of paper are used: strip-cut and rough-torn, allowing for a comparative analysis of their performance.

3.1 Material Sourcing and Prototype Development

Shredded paper is collected from CLINex Solutions, ensuring a consistent supply of recycled materials. Beeswax is used as a natural binding agent, enhancing the combustibility and burn duration of the fire cubes. The paper is soaked in melted beeswax and molded into cubes, which are then frozen for 24 hours to solidify.

3.2 User Testing and Feedback

A controlled testing environment is used to evaluate the ignition and burn performance of the fire cubes. A small group of users is surveyed to gather feedback on the ease of use, burn duration, and overall satisfaction with the product. The survey is conducted using Google Forms, and the results are analyzed to identify areas for improvement.

3.3 Data Analysis

The performance of the fire cubes is evaluated based on three key factors: burn duration, ignition strength, and user satisfaction. The results are compared between the two paper textures (strip-cut and rough-torn) to determine the most effective option for fire cube production.

4. Results and Discussion

The findings of this study reveal that rough-torn paper outperforms strip-cut paper in terms of burn duration and ignition strength. The rough-torn paper burns for an average of 21 minutes, compared to 19 minutes for the strip-cut paper, making it a more effective option for outdoor activities requiring a longer-lasting flame. Additionally, the rough-torn paper produces a stronger initial ignition, which is beneficial for starting fires in challenging conditions (Smith, 2020).

4.1 User Testing Results

User feedback indicates high satisfaction with the fire cubes, particularly in terms of ease of use and environmental benefits. The following table summarizes the results of the user testing:

Table 1: User Feedback on Fire Cube Performance

No	Question	Mean Score	Result
1	I find the fire starter cubes easy to ignite and start a fire quickly.	4.47	High
2	The burn duration of the fire cubes is sufficient for my outdoor activities.	4.53	High
3	I appreciate that the fire cubes are made from sustainable, waste-based materials.	4.58	High
4	The size of the fire cubes is convenient for storage and transportation.	4.49	High
5	I feel confident using the fire cubes because they contain no synthetic chemicals.	4.60	High
6	The fire cubes offer good value for their price compared to other fire-starting options.	4.55	High
Overall Results		4.54	High

Participants appreciated the eco-friendly nature of the product and its effectiveness in outdoor settings. The study also highlights the economic viability of mass-producing fire cubes, with a cost analysis showing that the production cost per cube is approximately RM 0.82 (GreenBiz Editors, 2022).

5. Conclusion and Recommendations

This study demonstrates the potential of recycled paper waste in creating sustainable fire starter cubes that meet the needs of outdoor enthusiasts. The rough-torn paper prototype outperforms the strip-cut variant in terms of burn duration and ignition strength, making it the preferred option for fire cube production. The collaboration with CLINex Solutions ensures a consistent supply of recycled materials and provides valuable insights into sustainable waste management practices (Seuring & Müller, 2008).

Future research should focus on scaling up production and exploring additional applications for recycled paper waste. The findings of this study contribute to the growing body of research on sustainable product development and highlight the importance of industry-academia collaboration in driving innovation (Wang et al., 2019)

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DATA KESELURUHAN ARTIKEL
DIGEST *SMART* GREEN 2025

Analisis Keseluruhan Artikel Digest Smart Green PMK

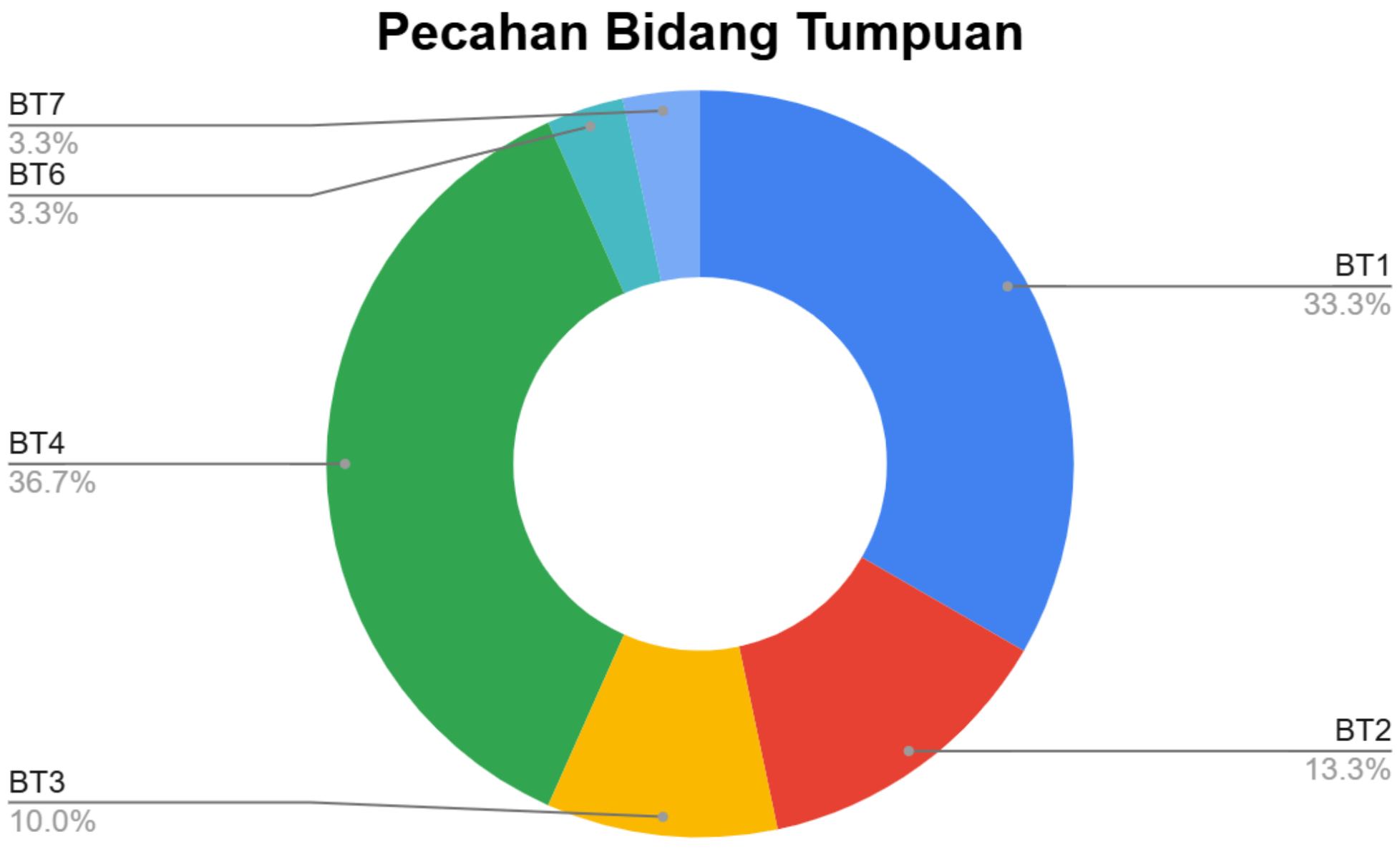
Penyertaan Mengikut Bidang Tumpuan

Walaupun Digest Smart Green PMK pertama kali dilaksanakan namun telah berjaya mencatatkan pengumpulan 30 artikel untuk semua bidang tumpuan (BT) seperti Jadual 1.

Jadual 1: Pecahan penyertaan mengikut bidang tumpuan (BT)

Pecahan Penyertaan	BT1	BT2	BT3	BT4	BT5	BT6	BT7
	10	4	3	11	0	1	1

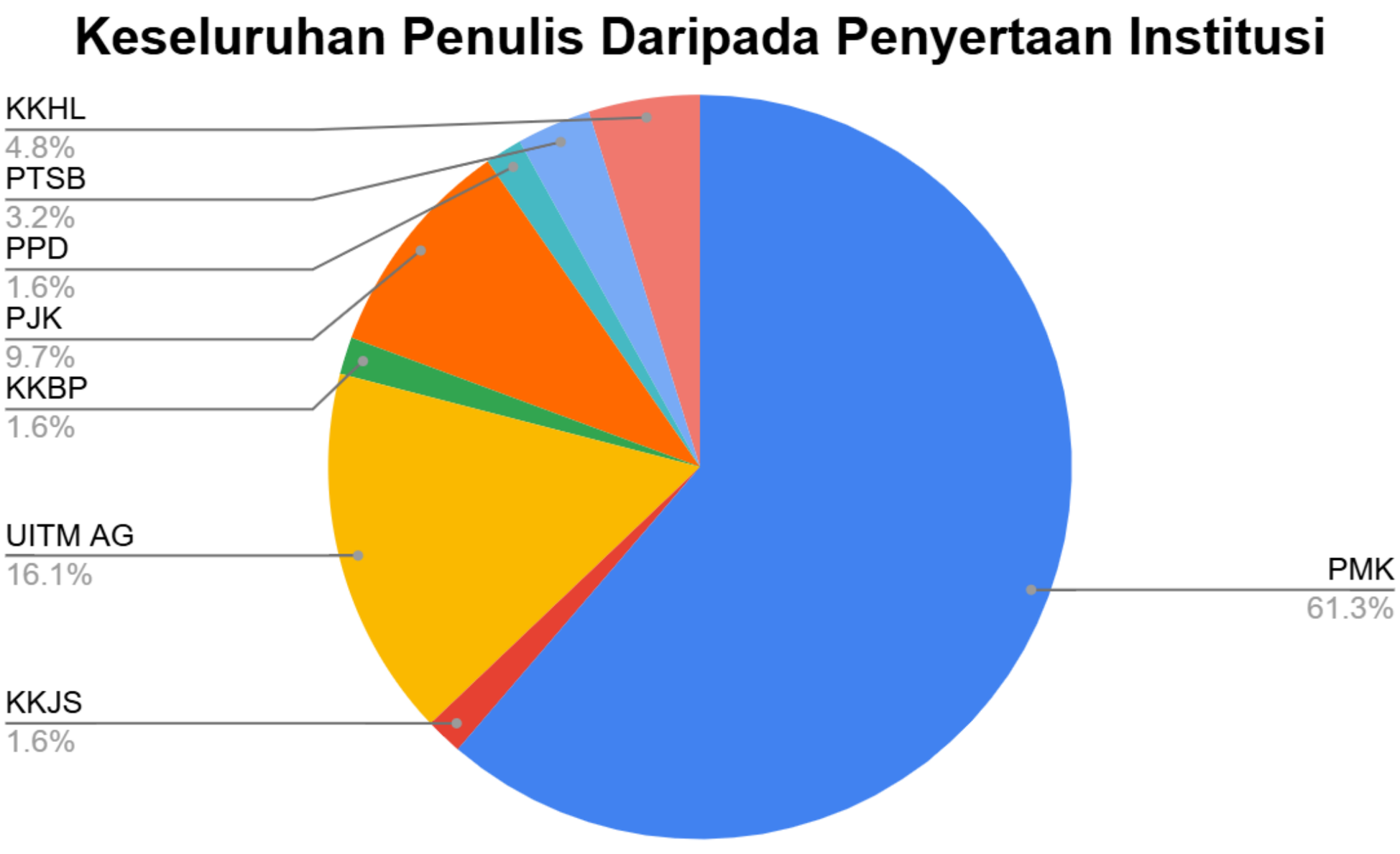
Rajah 2 menunjukkan bidang tumpuan yang paling popular adalah BT4: Pengurusan Sisa sebanyak 11 penyertaan (36.7%) dan BT1: Pengurusan Pendidikan dan Penyelidikan sebanyak 10 penyertaan (33.3%). Manakala bidang tumpuan yang kurang popular seperti BT6: Pengangkutan, BT7: Perolehan Hijau yang masing-masing hanya mencatatkan 1 penyertaan sahaja (3.3%) dan BT5: Pengurusan Air langsung tidak mendapat sambutan (0%).



Rajah 2: Pecahan polulariti bidang tumpuan

Bagi menggalakkan penulisan dalam BT yang tidak popular ini, Smart Green PMK telah melaksanakan aktiviti pembudayaan hijau seperti pertandingan Inovasi Sistem Pengumpulan Air Hujan (BT5: Pengurusan Air) bermula bulan April 2025. Smart Green PMK bersama-sama dengan Kluster Jaminan Kualiti PEKA PMK merancang mempertingkatkan program penyampaian maklumat berkaitan BT6: Pengangkutan dan BT7: Perolehan Hijau kepada semua warga PMK bermula Mei 2025.

Rajah 3 pula menunjukkan pecahan keseluruhan penulis artikel yang menyertai Digest Smart Green PMK.



Rajah 3: Keseluruhan penulis daripada institusi yang menyertai Digest Smart Green PMK

Digest Smart Green PMK telah menerima penyertaan dari Politeknik Melaka (61.3%), UiTM cawangan Alor Gajah (16.1%), Politeknik Jeli (9.7%), Kolej Komuniti Hulu Langat (4.8%), Politeknik Tuanku Sultanah Bahiyah (3.2%), Politeknik Port Dickson (1.6%), Kolej Komuniti Batu Pahat (1.6%) dan Kolej Komuniti Jasin (1.6%).

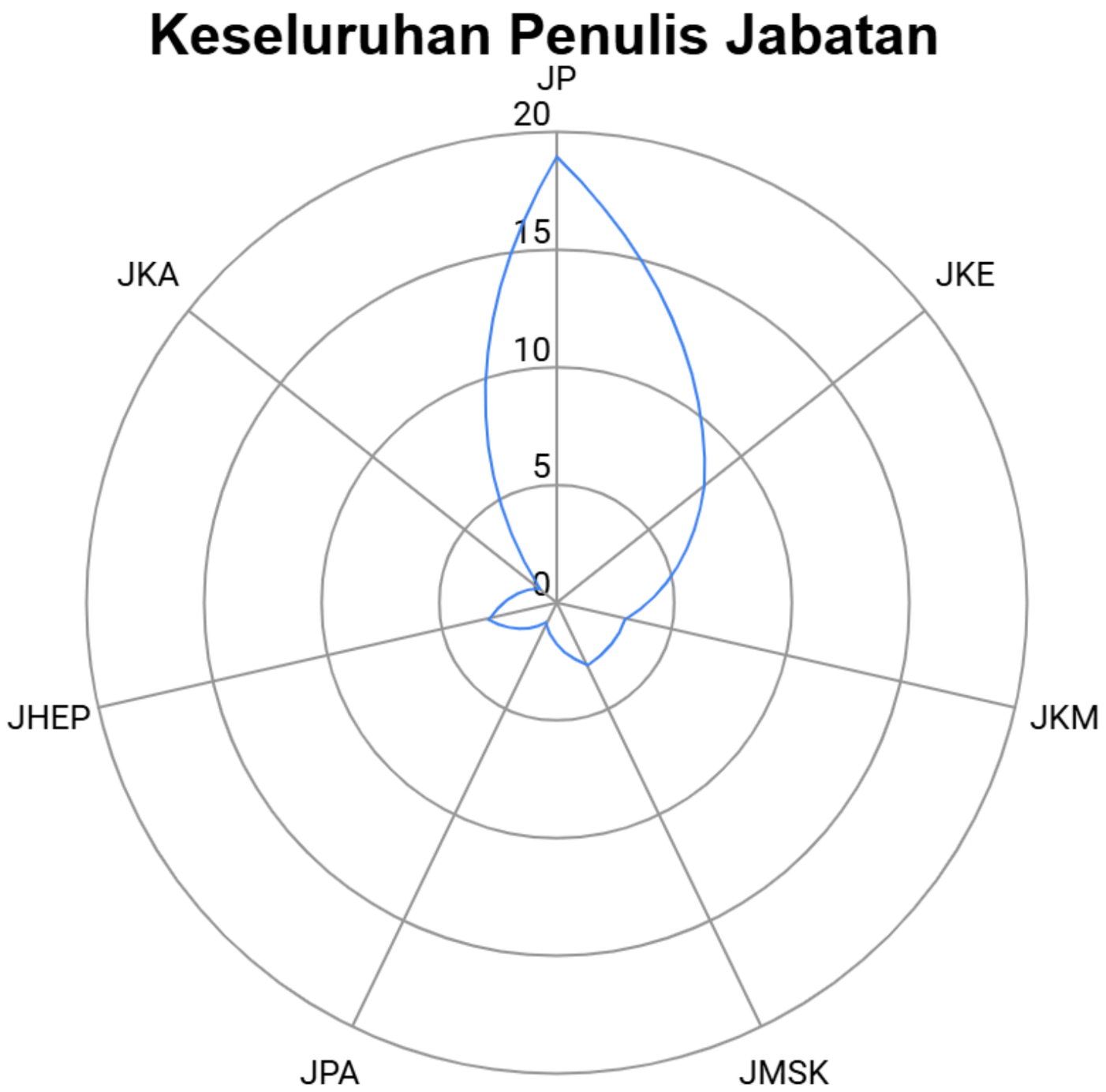
Jumlah keseluruhan penulis merujuk kapada jumlah penulis terkumpul bagi keseluruhan 30 artikel yang diterima. Jadual 2 menunjukkan bilangan penulis artikel terkumpul iaitu sebanyak 62 orang.

Jadual 2: Bilangan penulis artikel terkumpul dari setiap institusi

Keseluruhan Penulis Institusi	Politeknik Melaka	KK Jasin	UiTM cawangan Alor Gajah	KK Batu Pahat	Politeknik Jeli	Politeknik Port Dickson	Politeknik Tuanku Sultanah Bahiyah	KK Hulu Langat	JUMLAH
	38	1	10	1	6	1	2	3	62

Bagi menggalakkan penyertaan daripada institusi lain pada masa akan datang, Smart Green PMK serta Unit Penyelidikan, Inovasi dan Komersial (UPIK) PMK mencadangkan penulisan terbaik akan dimasukkan dalam Journal of Engineering and Social Science (JESSc) terbitan Politeknik Melaka.

Rajah 4 menunjukkan penyertaan setiap Jabatan di Politeknik Melaka bagi Digest Smart Green PMK.



Rajah 4: Penyertaan setiap jabatan di Politeknik Melaka dalam Digest Smart Green PMK

Secara keseluruhannya Jabatan Perdagangan (JP) mengungguli penyertaan artikel terkumpul terbanyak dengan 19 penulis. Seterusnya Jabatan Kejuruteraan Elektrik (JKE) sebanyak 8 penulis, Jabatan Kejuruteraan Mekanikal (JKM), Jabatan Matematik Sains dan Kejuruteraan (JMSK) dan Jabatan Hal Ehwal Pelajar (JHEP) masing-masing sebanyak 3 penulis.

Pencapaian Digest Smart Green PMK amat menggalakkan dengan jumlah terkumpul penulis setiap Jabatan di Politeknik Melaka adalah sebanyak 38 orang seperti tertera dalam Jadual 3.

Jadual 3: Bilangan penulis artikel terkumpul dari setiap Jabatan di Politeknik Melaka

	JP	JKE	JKM	JMSK	JPA	JHEP	JKA	Jumlah
Keseluruhan Penulis Jabatan	19	8	3	3	1	3	1	38

Walaupun Politeknik Melaka telah berjaya meningkatkan elemen pembudayaan hijau di kalangan warga PMK bermula tahun 2024. Namun begitu, setiap jabatan masih perlu mengembleng tenaga merangsang potensi warga masing-masing melalui aktiviti inovasi, kajian dan penulisan berkaitan teknologi hijau.

- SMART GREEN PMK -

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