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ENHANCING SUSTAINABILITY AWARENESS THROUGH EXPERIENTIAL STEM LEARNING: A COMMUNITY- BASED POLYMER EDUCATION APPROACH

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Abstract:

Environmental sustainability has become the main focus of STEM education in preparing students to address global environmental challenges. However, many pre-university students still have limited knowledge of polymer sustainability. Their understanding of plastics and rubber is often linked mainly to environmental pollution, as they have limited opportunities to learn about sustainable material management and how polymers are used in real-life applications. Therefore, this study aimed to evaluate the effectiveness of an experiential STEM learning approach in improving sustainability awareness through a community-based polymer technology education programme. The programme involved 35 science stream students from a pre-university institution and was facilitated by final-year undergraduate students specialising in polymer technology. The intervention consisted of an interactive sustainability talk addressing environmental pollution, responsible material management, misconceptions about polymers, and the role of recycling and the circular economy, followed by hands-on STEM activities and exhibition booths showcasing undergraduate research on sulfur devulcanisation, recycled polymer products, nanotechnology, waste-based polyurethane synthesis, and sustainable 3D printing. A pre- and post-intervention survey was conducted to assess students' sustainability awareness and understanding of polymer-related environmental issues. The findings showed that awareness of plastic sustainability increased from 3.49 to 4.32, while awareness of carbon sustainability improved from 3.29 to 4.32. Students also demonstrated greater familiarity with STEM-related activities, improved understanding of sustainable material practices, and increased interest in sustainability-related STEM topics after participating in the programme. The findings indicate that experiential and community-based STEM learning is an effective educational approach for enhancing sustainability awareness, correcting misconceptions about polymers, and making complex scientific concepts more meaningful and accessible to pre-university students, while strengthening their appreciation of the role of polymers in sustainable development.

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Community Engagement, Experiential Learning, Polymer Technology, STEM Education, Sustainability Awareness



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Introduction

Sustainability has become an increasingly important global issue, particularly in relation to plastic waste, excessive material consumption, and environmental degradation (Aravind et al., 2026). As these challenges continue to grow, STEM education has gained greater attention as

an important platform for preparing students with the knowledge, critical thinking, creativity, and problem-solving skills needed to address real-world environmental issues through interactive and hands-on learning experiences (Muhammad et al., 2026).

Despite this growing emphasis, many pre-university students still have limited exposure to applied concepts related to materials and polymer science, even though these areas play a significant role in everyday life and environmental sustainability. As a result, students may understand sustainability issues at a general level but lack deeper awareness of how polymers and material management contribute to sustainable solutions.

From a scientific perspective, polymer materials play a significant role in modern society due to their versatility, durability, and widespread use in industries such as packaging, construction, and manufacturing. At the same time, these properties contribute to long-term environmental challenges, including waste accumulation and recycling difficulties (Widiastuti et al., 2025). Understanding sustainable approaches such as recycling technologies, material innovation, and waste-to-resource strategies is therefore essential. However, these concepts are often delivered in abstract or highly technical forms, making them less accessible to students at the pre-university level.

This gap highlights a key educational challenge: how to effectively translate advanced scientific knowledge into meaningful and engaging learning experiences that can enhance students' understanding of sustainability. Traditional teaching approaches, which rely heavily on theoretical instruction, may not sufficiently support the development of practical awareness or foster interest in STEM-related sustainability issues.

To address this challenge, an experiential STEM learning program was designed by transforming undergraduate research projects into interactive educational booths. Each booth was carefully structured to represent a key sustainability theme within polymer science, technology and engineering while maintaining scientific authenticity. For instance, the topic on sulfur devulcanisation introduced students to rubber recycling technologies and the concept of breaking crosslinked networks to enable material reuse, highlighting the importance of circular economy practices (Dorigato et al., 2023). Similarly, the development of polyurethane from waste cooking oil demonstrated the conversion of waste into valuable polymeric materials, reinforcing the concept of resource recovery and bio-based alternatives (Cappello et al., 2024).

Advanced material innovations were also introduced through simplified demonstrations. The tri-filler epoxy system and nanoparticle-based activities exposed students to the role of material engineering in enhancing functional properties such as thermal conductivity and performance efficiency, linking these innovations to energy-saving applications (Sathishkumar et al., 2021). In addition, the production of durable flooring from recycled EPDM emphasised mechanical recycling and value-added product development, while eco-enhanced PLA/LLDPE composites illustrated the integration of plant-based fillers as a strategy to reduce environmental impact (Trivedi et al., 2023).

Furthermore, the sustainable 3D printing booth provided insights into responsible manufacturing practices, encouraging students to consider material selection and waste reduction in emerging technologies (Agrawal & Bhat, 2025). Collectively, these activities enabled students to explore sustainability from multiple perspectives, including recycling,

material innovation, bio-based resources, and green manufacturing, through hands-on and visually engaging experiences.

Experiential learning has been widely recognised as a potential solution to enhance student engagement, as it promotes active participation, hands-on interaction, and contextualised understanding (Kong, 2021). When combined with community-based approaches, it further facilitates knowledge exchange between different educational levels. In this context, translating undergraduate research into interactive learning modules represents a promising strategy to bridge the gap between advanced science and school-level understanding.

Despite these potential benefits, there is limited empirical evidence on the effectiveness of experiential, research-based polymer education in improving sustainability awareness among pre-university students. In particular, the impact of transforming final-year research projects into interactive learning experiences has not been extensively explored.

Therefore, this study aims to evaluate the effectiveness of an experiential STEM learning approach in improving sustainability awareness among pre-university students through research-based polymer education activities. The programme was designed to make complex scientific concepts easier to understand through interactive and hands-on activities related to plastics, rubber, recycling technologies, and sustainable material management.

The study also explores how experiential learning can encourage students to become more interested in STEM and sustainability-related issues while helping them realise that polymers are an essential part of everyday life. The programme was designed to change the common perception that polymers are entirely harmful to the environment by showing students that environmental problems are often caused by irresponsible human behaviour and poor waste management, rather than the materials themselves (Yang et al., 2026). At the same time, students were exposed to the many benefits and practical uses of polymers in daily life, together with the importance of using, managing, and recycling these materials responsibly to support sustainability.

In addition, the programme provided undergraduate facilitators with opportunities to strengthen their communication and knowledge translation skills by explaining advanced scientific concepts in a simpler and more relatable way to pre-university students. This study involved a small-scale community-based educational intervention consisting of 35 science stream pre-university students. Although the sample size is limited, the study provides preliminary insights into the effectiveness of experiential STEM learning in enhancing sustainability awareness related to polymer education.

Literature Review

The integration of circular economy principles into higher education requires strong empirical validation that connects existing literature with practical teaching frameworks. Based on the synthesized data from the mapping matrix shown in Table 1, the justification for conducting this research is structured around five core pillars: sustainability awareness and circular polymer education, theoretical perspectives on sustainability awareness, polymer sustainability education and recycling awareness, experiential STEM learning in sustainability education, and community-based learning and social influence. These five interrelated dimensions provide

a complete conceptual framework for analyzing how structured learning experiences shape students' eco-literacy and long-term habits.

Sustainability Awareness and the Need for Circular Polymer Education

The rising global dependence on plastic materials significantly contributes to environmental pollution and waste accumulation. Conventional linear economic practices based on the "take, make, and dispose" concept have intensified plastic waste generation, resulting in severe environmental degradation and growing concerns regarding microplastic contamination. Several studies focus heavily on the structural integration of environmental sustainability and circular design rules into general education to cultivate lifelong literacy. Research by Khajuria (2025), Kowasch (2022), and Yan and Cheng (2026) highlight the importance of embedding Circular Economy (CE) education directly into existing systems to foster resource efficiency, system thinking, and circular literacy. This focus aligns with Shahidi Hamedani et al. (2026), who explore how higher education institutions can effectively transition into "mindset infrastructures" to advance United Nations Sustainable Development Goal 12 (SDG 12) and resource management.

A key contradiction appears in the operational pathways proposed by these researchers. Khajuria (2025) presents institutional case studies that compare top-down government mandates with bottom-up, grassroots frameworks. Conversely, Kowasch (2022) focuses entirely on teacher-training institutions, arguing that the true educational transition relies on preparing future educators rather than altering policy frameworks. Meanwhile, Yan and Cheng (2026) contrast with both by bypassing high-level policies or trainer programs, choosing instead to focus directly on student-level workshop interventions using circular design rules.

While these studies build a strong foundation for sustainability, they leave a notable gap regarding technical adaptation. Shahidi Hamedani et al. (2026) mention that past studies do not show how Society 5.0 technologies can explicitly help overcome interdisciplinary teaching resistance in circular polymer topics. Furthermore, Yan and Cheng (2026) stress that educators still lack dedicated pedagogical tools that effectively inspire sustainable development among diverse learners.

Conducting research in this specific area is crucial because circular concepts like resource efficiency and life-cycle thinking are currently included unevenly due to barriers like low awareness (Shahidi Hamedani et al., 2026). Without a clear educational framework, students will remain vulnerable to misleading green advertisements and will fail to evaluate sustainable materials properly (Kopnina, 2019).

Theoretical Perspective on Sustainability Awareness

Sustainability awareness is closely linked to behavioral and cognitive theories that explain how environmental knowledge influences human action. Social Cognitive Theory suggests that behavior is shaped through the interaction between personal cognition, environmental influences, and social experiences (Teama et al., 2026). Scholars within this area focus on using established educational and psychosocial frameworks to explain how sustainable mindsets are formed. Adebo and Aladelusi (2025) integrate the theory of basic human values with social cognitive theory to understand how personal virtues translate into environmental outcomes. This theoretical approach is shared by Shao et al. (2025), who explore the theoretical paradigm

shifts required for advanced polymer material sciences, and Zaky (2019), who relies on the affective domain of transformative learning theories to explain student behavioral growth.

The primary contradiction lies in the source of behavioral influence. Adebo and Aladelusi (2025) argue that individual internal human values (such as universalism and benevolence) act as the main driver for sustainability action when supported by physical spaces. In contrast, Zaky (2019) focuses less on fixed internal values and more on the flexible process of recontextualizing learned knowledge through adult experiences. This differs from Shao et al. (2025), who approach the issue from a purely chemical perspective, arguing that theoretical awareness must stem from a deep scientific understanding of covalent bonding and material behavior.

Existing literature lacks empirical evidence on how physical campus greenness can actively mediate and translate specific human values into long-term environmental behavior (Adebo & Aladelusi, 2025). Additionally, there is an unresolved gap in understanding the theoretical alignment of policy and curriculum redesign across different national contexts (Khajuria, 2025).

Research into these theoretical perspectives is needed to establish a clear pathway between abstract knowledge and physical practice. Investigating how physical campus greenness guides student actions allows institutions to design targeted spaces and practical learning modules that foster active involvement (Adebo & Aladelusi, 2025).

Polymer Sustainability Education and Recycling Awareness

Polymer sustainability education has become increasingly important in addressing misconceptions regarding plastics and environmentally friendly materials. One of the major misconceptions among consumers and students involves biodegradable plastics, particularly the assumption that such materials naturally decompose under normal environmental conditions. Research under this pillar concentrates on the specialized problems of plastic pollution, polymer life cycles, and waste management (Oladele et al., 2026). De Waard et al. (2022) examine instructional methodologies designed to give chemistry students a critical view of plastic production. Similarly, Shaherani et al. (2024) and Shao et al. (2017) investigate student knowledge, behaviors, and educational visions regarding campus plastic waste management and the mitigation of hazardous microplastics.

Students often lack understanding of the various recycling approaches used in polymer waste management. A significant gap exists because current chemistry lessons do not provide students with a complete and coherent understanding of the quantitative recycling phase of polymers (De Waard et al., 2022). Furthermore, standard mechanical and chemical recycling methods remain highly insufficient for disposing of crosslinked rubber waste (Shao et al., 2025). Without proper education, these misunderstandings may contribute to improper waste disposal practices (Titone et al., 2025).

This research is justified because plastic pollution and microplastics represent an urgent environmental crisis that requires a clear vision for biodegradable alternatives (Shao et al., 2017). Teaching life-cycle assessments (LCA) is highly relevant because it increases students' awareness of the complexity surrounding sustainability issues (De Waard et al., 2022).

Experiential STEM Learning in Sustainability Education

Experiential learning is widely recognized as an effective educational approach for promoting student engagement and meaningful understanding. Within STEM education, hands-on activities encourage students to actively participate in problem-solving, experimentation, collaboration, and critical thinking processes. These authors analyze how hands-on, experiential learning and project-based STEM interventions help students understand sustainability (Yao et al., 2024). Michael et al. (2025) use Kolb's learning cycle to guide hands-on activities, which matches the experimental laboratory approach of De Waard et al. (2022). Susilowati et al. (2025) also apply a Research-Based Learning (RBL) STEM approach, similar to the practical material-driven workshops used by Yan and Cheng (2026) to improve technical and creative thinking.

Experiential STEM learning provides students with opportunities to connect theoretical concepts with real-world sustainability challenges. De Waard et al. (2022) evaluate structured laboratory experiments for pre-university chemistry students in secondary classrooms. Susilowati et al. (2025) look at primary and elementary education, using basic crafting activities like transforming plastic spoons into decorative lamps. These school-centric models contrast with Michael et al. (2025), who move completely out of schools to apply experiential STEM learning to rural community settings using local materials like bamboo and lemongrass. There is currently limited exploration on how basic material engineering activities can be standardly structured in elementary science curricula to boost green innovation skills (Susilowati et al., 2025). In addition, researchers need to evaluate how hands-on learning can effectively overcome the limitations of traditional, non-experiential education in isolated settings (Michael et al., 2025). This research is required because combining theoretical STEM instruction with practical activities significantly improves student engagement and environmental behavior (Yan & Cheng, 2026). Experiential activities successfully evoke deep life cycle thinking that traditional, lecture-based learning cannot achieve (De Waard et al., 2022).

Community-based Learning and Social Influence on Sustainable Practices

Community-based educational approaches provide valuable opportunities to extend sustainability learning beyond classroom settings (Chowdhury & Alzarrad, 2025). Michael et al. (2025) examine student-led service learning that empowers local populations, while Khajuria (2025) evaluates how grassroots communities and non-governmental organizations (NGOs) drive recycling pilots. This attention to collective behavior is supported by Shao et al. (2017), Zaky (2019) and Septi Viantri Kurdaningsih & Esa Zahirah (2025), who view local community engagement as essential for real-world environmental transitions.

The main contradiction arises when looking at the communication channels used to exert social influence. Shao et al. (2017) emphasize digital and social networking platforms as the main information source for recycling management. Conversely, Michael et al. (2025) focus on direct, face-to-face community work in rural settings, explicitly pointing out that digital communication is unreliable in areas with poor infrastructure. Both differ from Khajuria (2025), who treats social influence as a formal partnership between local NGOs and regional governments.

Up until now, research has not deeply explored how social network groups can be structurally aligned with local national policies to change community behavior (Shao et al., 2017). There is also a distinct gap regarding how the limited availability of locally relevant sustainability programs affects community empowerment in isolated areas (Michael et al., 2025).

This research is fully justified because building awareness of local community issues ensures stable development and bridges the gap between academic knowledge and the real world (Zaky, 2019). Student-led social initiatives empower local populations, allowing isolated communities to gain practical sustainability knowledge and confidence in new green skills (Michael et al., 2025).

Bridging the Conceptual and Pedagogical Gaps

Current literature heavily emphasizes general environmental conservation, yet limited studies specifically explore the integration of experiential Science, Technology, Engineering, and Mathematics (STEM) programs with circular polymer education in community-based settings (Shahidi Hamedani et al., 2026). Most existing research focuses on broad environmental awareness without addressing the practical roles of synthetic polymers, local recycling practices, and sustainable material management in everyday life (Shaherani et al. 2024). Furthermore, pre-university students are routinely exposed to abstract sustainability concepts without receiving sufficient opportunities for hands-on learning or real-world application (De Waard et al., 2022).

This pedagogical limitation creates an operational gap where young learners fail to understand how post-consumer materials are recovered and processed (Yan & Cheng, 2026). Consequently, there is an urgent need for an interactive and experience-based educational framework that helps students understand complex ecological issues (Susilowati et al., 2025). By deploying targeted academic talks and technical exhibition booths, this study establishes a clear methodological pathway to bridge these identified literature gaps (Michael et al., 2025). Ultimately, this intervention provides empirical proof of how localized technical knowledge can directly improve learner outcomes and foster a balanced public perception of polymers in modern society (Shao et al., 2025).

Table 1: Classification of References Based on Sustainability Awareness, Experiential Learning, and Polymer Education Factors

References	Sustainability awareness and circular polymer education	Theoretical perspectives on sustainability awareness	Polymer sustainability education and recycling awareness	Experiential STEM learning in sustainability education	Community-based learning and social influence
Adebo and Aladelusi (2025)		This paper combines the theory of basic human values with social cognitive theory to understand student literacy. It justifies how personal values can be guided by campus greenness to influence actions. <i>Research Gap:</i> Nevertheless, existing literature lacks empirical evidence on how physical campus greenness can actively mediate and translate these specific human values into long-term environmental behavior.		This study recommends that universities design green spaces and practical learning modules. These efforts encourage active student involvement and experiential outcomes.	
De Waard et al. (2022)	This research reports on a lesson series focusing on sustainability and life cycle assessment (LCA) in chemistry education. It is relevant because it increases students' awareness of the complexity surrounding sustainability issues. <i>Research Gap:</i> Students need more critical views and insights into the entire life cycle of products.		This article discusses a lesson series focused on engaging pre-university chemistry students in plastic sustainability and Life Cycle Assessment (LCA). The lessons successfully evoke a critical view and life cycle thinking regarding the production and use of plastics. <i>Research Gap:</i> Even so, current chemistry	Preuniversity students engaged in reading, answering questions, and conducting laboratory experiments based on LCA stages. It is relevant because these experiential activities successfully evoked qualitative life cycle thinking in chemistry students. <i>Research Gap:</i> Exploring how this experiential step can effectively bridge the transition toward complex quantitative assessments in STEM.	

			lessons do not provide students with a complete and coherent understanding of the quantitative recycling phase of polymers.	
Khajuria (2025)	This paper examines integrating Circular Economy education into Education for Sustainable Development to foster resource efficiency. It is relevant because it promotes systems thinking for global sustainability at various educational levels. However, less is known about how governance, cultural, and economic factors influence the integration of this awareness, which justifies further research.	The study provides comparative case studies of Finland, Greece, and Vietnam to reveal different integration models. It is relevant because it builds a conceptual typology of theoretical strategies like top-down, grassroots, and hybrid frameworks. <i>Research Gap:</i> Understanding the theoretical alignment of policy and curriculum redesign across different national contexts.		The research highlights grassroots community and NGO-led pilots in Greece as a specific educational strategy. It is relevant because it shows how local social influence and community involvement can drive circular economy education. <i>Research Gap:</i> How to scale these localized, community-based models into broader systemic change for global sustainability.
Kopnina (2019)	This study reviews how circular economy and Cradle to Cradle frameworks can be used in business courses. It justifies teaching these topics so students do not get fooled by misleading green ads.			This paper suggests that applying ideal circular ideas in experiential learning strengthens the curriculum. It helps future responsible citizens evaluate sustainable materials properly.
Kowasch (2022)	This study explores how alternative concepts like the circular economy and zero waste can be included in teacher training. It justifies the need to prepare future teachers			

	to lead environmental education transitions.		
Michael et al. (2025)	This study evaluates a student-led service-learning program to embed circular economy concepts in Sarawak. It is relevant because it increases practical sustainability knowledge and awareness among participants. <i>Research Gap:</i> Climate education in rural communities is often constrained by poor digital infrastructure and a lack of local examples.	The program uses Kolb's learning cycle to guide hands-on activities like upcycling bamboo waste and extracting essential oils. It is relevant because it proves that experiential STEM learning leads to significant knowledge gains and increased confidence in new skills. <i>Research Gap:</i> Need to evaluate how hands-on learning can effectively overcome the limitations of traditional education in rural settings.	This initiative was implemented directly with 24 villagers in a rural community setting. It is relevant because it empowers local populations through student-led social initiatives and interactions. <i>Research Gap:</i> How the limited availability of locally relevant sustainability programs affects community empowerment in isolated areas.
Shaherani et al. (2024)		This research investigates student knowledge and behaviors regarding campus plastic waste management. It highlights that environmental education helps maintain green campus goals.	
Shahidi Hamedani et al. (2026)	This study explores how Malaysian higher education institutions integrate circular economy principles and SDG 12 into their courses. The findings show that concepts like resource efficiency and		

	life-cycle thinking are included unevenly due to barriers like low awareness . <i>Research Gap:</i> Past studies do not show how Society 5.0 technologies can explicitly help overcome interdisciplinary teaching resistance in circular polymer topics.			
Shao et al. (2017)		This study looks at the shift towards sustainable polymers and the problem of hazardous microplastics. It provides a vision for biodegradable materials to resolve plastic management issues.	This article discusses complementary issues in STEM education to build a sustainable material future. It links polymer science with student learning to achieve vision goals.	This study notes that females highly support raising awareness about plastic pollution in schools. It also reveals that social networking is the main information source for recycling. <i>Research Gap:</i> Up until now, research has not deeply explored how social network groups can be structurally aligned with local national policies like Saudi Vision 2030 to change community behavior.
Shao et al. (2025)	This paper discusses the paradigm shift toward sustainable materials and dynamic covalent bonding in polymers. It is relevant because it provides a theoretical perspective on the future possibilities of biodegradable rubbery materials. <i>Research Gap:</i>	The authors highlight the urgent need to minimize hazardous microplastics derived from highly crosslinked rubber wastes. It is relevant because it envisions a realistic educational and scientific pathway	The article addresses complementary issues in STEM education regarding advanced polymer science. It is relevant because it connects complex chemistry concepts with educational strategies for a comprehensive sustainability vision.	

Susilowati et al. (2025)	Rubbery materials have received comparatively less theoretical and practical attention than general plastics.	toward biodegradable rubber alternatives. <i>Research Gap:</i> Current mechanical and chemical recycling methods are insufficient for disposing of crosslinked rubber waste.	<i>Research Gap:</i> Need to integrate advanced polymer sustainability topics into STEM education to relate scientific solutions to the broader society.
			This study implements Research-Based Learning (RBL) by transforming used plastic spoons into decorative lamps. It justifies how the STEM approach successfully improves primary students' creative thinking. <i>Research Gap:</i> But, there is still limited exploration on how basic material engineering activities can be standardly structured in elementary science curricula to boost green innovation skills.
Yan and Cheng (2026)	This research focuses on adding circular design principles into education to increase sustainability literacy. It uses workshops to show how waste plastic can be turned into useful products. <i>Research Gap:</i> Need for pedagogical tools that effectively inspire sustainable	This paper addresses the major problem of plastic pollution by focusing on recycling plastic bags. The workshop model proves that working with recycled polymers changes environmental behavior. <i>Research Gap:</i> Practical frameworks for	This article shows that practical material-driven workshops improve student technical skills and creative thinking. Experiential learning with recycled items helps students learn about environmental practices effectively. It is relevant because combining theoretical STEM instruction with

development among diverse learners.		integrating material science with circular design education.	practical activities significantly improves student engagement.	
			<i>Research Gap:</i> How experiential learning with recycled materials can be structured to effectively cultivate practical design skills.	
Zaky (2019)	This paper discusses the importance of adult learners' affective domain in transformative learning. It argues that recontextualizing learned knowledge allows students to handle community issues.		This study explains that Experiential Learning (EL) helps build important transferable and communication skills. It promotes adding practical field experiences into the main curriculum.	This paper states that building awareness of local community issues ensures stable development. It shows that infield education bridges academic knowledge with the real world of work.

Methodology

Research Design

This study employed a quantitative quasi-experimental research design using a one-group pre-test and post-test approach. The design was selected to evaluate the effectiveness of an experiential STEM learning intervention in enhancing students' sustainability awareness related to polymer education. The study focused on measuring changes in students' knowledge and awareness before and after participating in a community-based educational program.

Participants

The participants of this study consisted of 35 science stream students from a pre-university institution in Shah Alam, Selangor, Malaysia. The selection of participants was based on convenience sampling, involving students who participated in a community-based STEM outreach program related to polymer sustainability. Although the sample size is relatively small, it is appropriate for exploratory and intervention-based educational research aimed at assessing preliminary impacts of the program.

Educational Intervention

The intervention was designed as a community-based experiential STEM learning program with a focus on polymer sustainability. It began with an awareness session intended to gently challenge a common perception among students—that plastics are entirely harmful. Instead, the session highlighted a more balanced view: polymers themselves are not inherently problematic, but their environmental impact depends on how they are used, managed, and disposed of. Given the continued importance of plastics in everyday life, students were encouraged to think more critically and realistically about sustainability, particularly in relation to responsible consumption and waste management.

The program then progressed into a series of hands-on and interactive learning activities. Students were introduced to fundamental concepts of polymer materials and their applications in daily products, alongside key environmental issues associated with plastic waste. The 3R principles (Reduce, Reuse, Recycle) were discussed in a contextualised manner to connect theory with practical relevance. Students also engaged in polymer identification activities and creative reuse tasks using plastic materials, conducted in small groups to promote collaboration, communication, and problem-solving.



Figure 1: Undergraduate Students Facilitating Experiential STEM Learning Through Interactive Polymer Research Showcase Activities for Pre-University Students

Overall, the intervention combined conceptual awareness with experiential learning to support deeper understanding. It aimed not only to strengthen STEM-related knowledge, but also to nurture a more informed and balanced perspective on polymer sustainability in a way that is relatable and grounded in real-world experience.

Research Instrument

Data were collected using a structured questionnaire administered before and after the intervention. The questionnaire consisted of items measuring students' sustainability awareness, understanding of polymer-related environmental issues, and knowledge of recycling practices.

The items were developed based on previous literature on sustainability education and adapted to suit the context of polymer education. The questionnaire used a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

The instrument covered several dimensions, including:

- Awareness of plastic and polymer environmental impact
- Understanding of recycling and waste management practices
- Knowledge of sustainable materials and circular economy concepts
- Attitudes towards sustainability practices

Data Collection Procedure

Data collection was carried out in three sequential stages to assess changes in students' sustainability awareness before and after the intervention.

In the first stage (pre-test phase), students were asked to complete a structured questionnaire prior to the implementation of the STEM intervention. This was conducted to establish their baseline level of awareness and understanding of sustainability, particularly in relation to polymer materials and environmental issues.

The second stage involved the intervention phase, where students participated in a community-based experiential STEM learning program focusing on polymer sustainability. This phase

included both awareness-building and hands-on activities designed to enhance students' understanding through direct engagement with real-world applications of STEM concepts.

In the final stage (post-test phase), students were required to respond to the same questionnaire after completing the program. This was done to evaluate any changes in their sustainability awareness and conceptual understanding following the intervention.

To encourage honest responses and minimise response bias, all questionnaires were collected anonymously throughout the data collection process.

Data Analysis

The collected data were analyzed using descriptive and inferential statistics. Descriptive analysis was used to determine the mean and standard deviation of students' responses in both pre-test and post-test stages.

To examine the effectiveness of the intervention, a paired sample t-test was conducted to compare the mean differences between pre-test and post-test scores. If the data did not meet normality assumptions, a non-parametric Wilcoxon signed-rank test was considered as an alternative.

The level of significance was set at $p < 0.05$.

Result and Discussion

This section presents the findings from the pre-test and post-test surveys conducted to evaluate the community-based experiential STEM learning program on polymer sustainability. The results include participants' demographic profiles, their baseline awareness and perceptions of polymer sustainability, the immediate impact of the intervention on sustainability awareness, and the effectiveness of the program activities in fostering students' interest and engagement in STEM (Science, Technology, Engineering, and Mathematics), particularly in polymer science.

Demographic Overview and Participant Profile

A total of 35 science stream students participated in the pre-event survey, comprising 22 female (63%) and 13 male students (37%) as in Table 1. The cohort distribution demonstrated a balanced representation across academic progressions, with Semester 1 accounting for 18 students (51%) and Semester 3 representing 17 students (49%). Engaging students during these initial semesters (Semesters 1 and 3) is highly strategic; this formative period represents a critical juncture where students establish academic trajectories and cultivate specific specialization interests within STEM fields.

For the post-event phase, 19 respondents successfully completed the evaluation (13 female, 6 males; 10 from Semester 3, 9 from Semester 1). A drop in respondent volume during post-event phases is common in voluntary educational assessments; however, this sample size remains robust and provides saturated data sufficient to gauge the immediate cognitive and affective impacts of the educational intervention.

Table 1: Demographic Profile of Survey Respondents

Demographic Variable	Pre-Event Phase (N=35)	Post-Event Phase (N=19)
Gender		
Female	22 (63%)	13 (68%)
Male	13 (37%)	6 (32%)
Academic Progression		
Semester		
Semester 1	18 (51%)	9 (47%)
Semester 3	17 (49%)	10 (53%)

Construct Reliability

To establish the internal consistency and reliability of the Likert-scale questions utilized in the evaluation instrument, Cronbach's alpha (α) was calculated using SPSS. The analysis yielded a Cronbach's alpha value of $\alpha = 0.842$ for the core tracking items. Since this value significantly exceeds the standard academic threshold of 0.70, the instrument demonstrates high reliability and structural consistency for educational evaluation.

Baseline Sustainability Awareness and the "Knowledge-Interest Gap" (Pre-Event Findings)

Utilizing a 5-point Likert scale as in Table 2, the pre-event survey indicated that students already possessed a moderate to high level of general awareness regarding sustainability issues, particularly in relation to plastics (mean = 3.49/5.00) and carbon sustainability (mean = 3.29/5.00). This suggests that environmental topics are not entirely new to the students and that prior exposure to sustainability concepts has been established through formal or informal education.

However, a notable gap was observed in students' familiarity with specific polymer-related academic pathways, particularly the Engineered Polymer Technology (EPT) programme (mean = 2.20/5.00). Similarly, interest in exploring polymer-focused academic programmes remained relatively low (mean = 2.57/5.00).

These findings suggest that while students are generally aware that plastic pollution is an environmental issue, they have limited understanding of how polymer science and engineering contribute to sustainable solutions. Many students initially viewed polymers simply as a source of environmental problems, without recognising their essential role in developing innovative materials, recycling technologies, and sustainable products. The EPT programme helped bridge this gap by connecting sustainability concepts with real-world polymer applications, allowing students to see polymers not only as materials that require responsible management but also as part of the solution to environmental challenges. This shift demonstrates how experiential STEM learning can transform general environmental awareness into a deeper understanding of science and its practical applications.

Table 2: Comparison of Pre-Event and Post-Event Sustainability Awareness Scores

Construct	Pre-Event Mean (n=35)	Post-Event Mean (n=19)	Interpretation
Awareness of plastic sustainability issues	3.49 / 5.00	4.32 / 5.00	Increased awareness
Importance of carbon sustainability	3.29 / 5.00	4.32 / 5.00	Strong improvement
Understanding carbon footprint/emissions	2.91 / 5.00*	4.26 / 5.00	Significant improvement
Familiarity with STEM activities	3.46 / 5.00*	4.26 / 5.00	Improved engagement
Interest in academic programme (EPT)	2.57 / 5.00	3.53 / 5.00	Moderate improvement

Intervention Impact: Shifting Environmental Perceptions and Boosting STEM Literacy (Post-Event Findings)

The post-event survey results demonstrated a clear improvement in students' sustainability awareness and understanding of polymer-related concepts as shown in Table 2. The highest-rated constructs were awareness of sustainability issues in plastics (mean = 4.32/5.00) and awareness of carbon sustainability importance (mean = 4.32/5.00). These results indicate that the experiential STEM programme was effective in reinforcing environmental awareness among participants.

Furthermore, students reported a strong understanding of carbon emissions and environmental footprint concepts (mean = 4.26/5.00), as well as familiarity with STEM-related activities (mean = 4.26/5.00). Importantly, 15 out of 19 respondents stated that they had gained new knowledge from the programme, suggesting that the intervention successfully achieved its educational objective of knowledge transfer.

In addition, students' familiarity with the Engineered Polymer Technology (EPT) discipline increased considerably after the programme, demonstrating the effectiveness of the outreach activities in introducing polymer science as a potential field of study. Although students also expressed greater interest in exploring the EPT programme, this remained the lowest-rated construct among the post-event measures (mean = 3.53/5.00). This suggests that while experiential STEM activities are effective in stimulating curiosity and improving awareness, additional initiatives such as career talks, academic mentoring, or programme information sessions may be needed to encourage students to consider polymer technology as a future academic pathway.

More importantly, the programme helped shift students' perception of polymers from being viewed solely as environmental pollutants to being recognised as valuable engineering materials whose environmental impact depends largely on responsible production, use, and end-of-life management. This change in perspective is particularly important, as it supports a more balanced understanding of sustainability that aligns with circular economy principles.

Evaluation of Showcase Topics

The study also examined students' interest in the scientific showcase topics presented throughout the programme as summarized in Table 3. Before the event, students showed the greatest interest in modern, technology-driven topics, with "3D Printing: Think Green, Print Smart" receiving the highest number of selections (32 responses), followed by "Magic of Mini Things: Nanotechnology" (21 responses). This suggests that students were initially more attracted to emerging technologies that are visually engaging, innovative, and closely associated with current technological advancements.

After participating in the programme, students' interests shifted towards topics that demonstrated the practical application of polymer science in addressing environmental challenges. "Magic of Mini Things: Nanotechnology" became the most popular showcase (14 responses, 73.7%), while "Sulfur Devulcanisation for Rubber Waste Management" showed the greatest increase in interest, rising from 12 selections in the pre-event survey to 13 out of 19 responses (68.4%) in the post-event survey. This increased interest suggests that the experiential STEM activities enabled students to better appreciate how polymer science and engineering can contribute to sustainable solutions through recycling, waste management, and circular economy practices (Ju et al., 2026).

Table 3: Distribution of Student Interest Across Showcase Topics

Showcase Topic	Pre-Event (N=35)*	Post-Event (N=19)*	Dynamics of Student Interest Trends
3D Printing: Think Green, Print Smart (Booth 8)	32 (91.4%)	11 (57.9%)	Remained highly popular; driven by the visual appeal of additive manufacturing.
Magic of Mini Things: Nanotechnology (Booth 4)	21 (60.0%)	14 (73.7%)	Surged to the primary rank post-intervention due to effective live demonstrations.
Sulfur Devulcanisation for Rubber Waste Management (Booth 3)	12 (34.3%)	13 (68.4%)	Substantial growth; students gravitated toward viable, real-world recycling solutions.
Durable Flooring from Recycled EPDM (Booth 5)	14 (40.0%)	10 (52.6%)	Steady, positive progression; highlighted commercially viable circular products.

**Note: Respondents were permitted to select multiple topics (Multiple-response data).*

More importantly, the programme appeared to reshape students' perceptions of polymers. Rather than viewing polymers simply as materials that contribute to environmental pollution, students began to recognise their important role in developing sustainable materials, recycling technologies, and innovative engineering solutions. The activities also reinforced the idea that the environmental impact of polymers depends largely on how these materials are produced, used, and managed throughout their life cycle, rather than on the materials themselves. This shift in understanding is particularly significant, as it reflects one of the key objectives of the programme—to promote a more balanced and informed perspective on polymers while fostering sustainability awareness through experiential STEM learning.

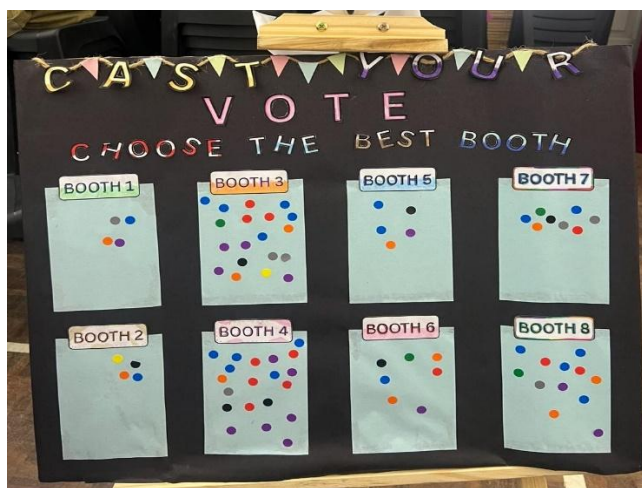


Figure 2: Distribution of Students' Votes for Preferred STEM Showcase Booths

Impact of Experiential STEM Learning Intervention

Overall, the comparison between pre-event and post-event survey results indicates a positive impact of the community-based experiential STEM programme. While pre-event data showed moderate general awareness but limited exposure to polymer-specific education pathways, post-event findings demonstrated increased understanding, stronger sustainability awareness, and improved familiarity with STEM applications.

The proportion of students reporting “gained new knowledge” (15 out of 19) further confirms the effectiveness of experiential learning in facilitating meaningful knowledge acquisition. Additionally, the increase in mean scores related to sustainability awareness and carbon literacy suggests that the intervention successfully addressed key learning gaps identified during the pre-event phase.

However, it is important to note that interest in formal academic pathways (e.g., EPT programme) remained comparatively lower even after the intervention (mean = 3.53). This suggests that while the programme effectively improves awareness and engagement, additional targeted promotional strategies may be required to strengthen student interest in specific academic programmes.

Conclusion

This study demonstrates that a community-based experiential STEM learning programme is effective in enhancing sustainability awareness among Form 6 students. The intervention significantly improved students' understanding of plastic sustainability, carbon footprint awareness, and engagement with STEM-related concepts.

The findings suggest that experiential learning approaches, particularly those involving polymer science applications such as nanotechnology, 3D printing, and recycling technologies, can effectively increase student interest and knowledge retention.

However, while awareness levels increased significantly, further strategies are required to convert this awareness into stronger interest in STEM academic pathways. Future programmes should incorporate career exposure, mentorship, and longitudinal engagement to strengthen the impact on student academic decision-making.

Overall, this study supports the integration of experiential STEM education as a powerful tool for promoting sustainability literacy and advancing circular economy awareness among pre-university students.

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References

- Adebo, A., & Aladelusi, K. (2025). Spatial examination of sustainability literacy: the interplay of campus greenness and students' values. *International Journal of Sustainability in Higher Education*, 26(1), 1-15.
- Agrawal, K., & Bhat, A. R. (2025). Advances in 3D printing with eco-friendly materials: a sustainable approach to manufacturing. In *RSC Sustainability* (Vol. 3, Number 6, pp. 2582–2604). Royal Society of Chemistry. <https://doi.org/10.1039/d4su00718b>
- Aravind, A., Mishra, S., & Das, S. R. (2026). Message framing and sustainability awareness: Experimental evidence for advancing reduce, reuse, and recycle practices. *Ecological Economics*, 248. <https://doi.org/10.1016/j.ecolecon.2026.109061>
- Cappello, M., Filippi, S., Rossi, D., Cinelli, P., Anguillesi, I., Camodeca, C., Orlandini, E., Polacco, G., & Seggiani, M. (2024). Waste-Cooking-Oil-Derived Polyols to Produce New Sustainable Rigid Polyurethane Foams. *Sustainability (Switzerland)*, 16(21). <https://doi.org/10.3390/su16219456>
- Chowdhury, S., & Alzarrad, A. (2025). Advancing Community-Based Education: Strategies, Challenges, and Future Directions for Scaling Impact in Higher Education. *Trends in Higher Education*, 4(2). <https://doi.org/10.3390/higheredu4020021>
- De Waard, E. F., Prins, G. T., & Van Joolingen, W. R. (2022). Engaging preuniversity students in sustainability and life cycle assessment in upper-secondary chemistry education: The case of polylactic acid (PLA). *Journal of Chemical Education*, 99(7), 2450-2458.
- Dorigato, A., Rigotti, D., & Fredi, G. (2023). Recent advances in the devulcanization technologies of industrially relevant sulfur-vulcanized elastomers. In *Advanced Industrial and Engineering Polymer Research* (Vol. 6, Number 3, pp. 288–309). KeAi Communications Co. <https://doi.org/10.1016/j.aiepr.2022.11.003>
- Ju, S., Chung, S., Park, S. B., Koo, J. M., Shin, G., Jeon, H., Park, J., & Oh, D. X. (2026). Reframing Biodegradable Plastic as an Effective, Chemically Recyclable Resource for a Circular Economy. In *Engineering*. Elsevier Ltd. <https://doi.org/10.1016/j.eng.2025.12.040>
- Khajuria, A. (2025). Integrating circular economy education into education for sustainable development: Models and typologies. *Environmental Education Research*, 31(2), 145-162.
- Kong, Y. (2021). The Role of Experiential Learning on Students' Motivation and Classroom Engagement. *Frontiers in Psychology*, 12. <https://doi.org/10.3389/fpsyg.2021.771272>
- Kopnina, H. (2019). Green-washing or green-wishing? Circular economy and cradle to cradle education in business schools. *Journal of Cleaner Production*, 208, 1112-1123.
- Kowasch, M. (2022). Potential of the alternative economic concepts circular economy and zero waste in teacher education. *International Journal of Sustainability in Higher Education*, 23(3), 512-529.
- Michael, F., Syafiq, M., & Rahman, A. (2025). Empowering circular economy education through student-led sustainability initiatives in rural Sarawak. *Chemical Engineering Transactions*, 122, 421-426.
- Muhammad, N., Mohamed, S. N., Zainuddin, H., Mohamed, Z., Kamisan, A.-S., Mohd Nor, A., & Jaafar, N. K. (2026). Effectiveness Of The Let's Generate Electricity From The Sun Program In Promoting Interest And Understanding In Stem Education. *International Journal of Education Psychology and Counseling*, 11(62), 1645. <https://doi.org/10.35631/IJEPC.1162097>
- Oladele, I. O., Oki, V. O., Maldaye, E. M., Makinde-Isola, B. A., Ajayi, M. A., Adelani, S. O., & Olanrewaju, F. O. (2026). Life cycle assessment, material sustainability metrics and

- technology readiness levels for lightweight polymer applications: A review on principles, recent processing and applications. In *Next Materials* (Vol. 12). Elsevier B.V. <https://doi.org/10.1016/j.nxmte.2026.102168>
- Sathishkumar, T. P., Navaneethakrishnan, P., & Maheskumar, P. (2021). Thermal stability and tribological behaviors of tri-fillers reinforced epoxy hybrid composites. *Applied Science and Engineering Progress*, 14(4), 727–737. <https://doi.org/10.14416/j.asep.2021.08.002>
- Septi Viantri Kurdaningsih, & Esa Zahirah. (2025). Implementation of Education-Based Community Service to Increase Environmental Awareness among Young People. *Sustainable Applied Modification Evidence Community*, 2(1), 55–61. <https://doi.org/10.69855/samec.v2i1.160>
- Shaherani, M. S., Azmi, N., & Yusuf, M. (2024). Plastic waste management and green campus initiatives: Assessing student knowledge and behavior. *Malaysian Journal of Environmental Management*, 25(1), 89-102.
- Shahidi Hamedani, S., Aslam, S., Mohamad, S., Mansori, S., & Hamedani, S. S. (2026). From awareness to action: Reimagining circular economy learning in Malaysian higher education. *Circular Economy and Sustainability*, 6(1), 110-125.
- Shao, Y., Mallory, R. C., Dugas, M., Flanagan, C., Ligon, C., & Burks, G. R. (2017). Advanced polymer options for microplastic mitigation: A socio-educational perspective. *Science of The Total Environment*, 598, 334-345.
- Shao, Y., Wang, X., & Zhang, H. (2025). Biodegradable elastomers and dynamic covalent networks: Theoretical pathways for sustainable rubber futures. *Chemistry - A European Journal*, 31(4), e20240012.
- Susilowati, M. E., Gita, R. S. D., Waris, W., & Susilo, D. K. (2025). Reconstructing the plastic spoons into lotus decorative lamps in RBL-STEM learning to enhance students' creativity. *AIP Conference Proceedings*, 3201(1), 020034.
- Teama, T., Deifalla, A., Dawoud, S. A., Ashraf, N., Shehata, A., & Khalil, R. (2026). Sustainability awareness assessment for university-level students in Cairo, Egypt. *Scientific Reports*, 16(1). <https://doi.org/10.1038/s41598-025-08575-1>
- Titone, V., Botta, L., & La Mantia, F. P. (2025). Mechanical Recycling of New and Challenging Polymer Systems: A Brief Overview. In *Macromolecular Materials and Engineering* (Vol. 310, Number 1). John Wiley and Sons Inc. <https://doi.org/10.1002/mame.202400275>
- Trivedi, A. K., Gupta, M. K., & Singh, H. (2023). PLA based biocomposites for sustainable products: A review. In *Advanced Industrial and Engineering Polymer Research* (Vol. 6, Number 4, pp. 382–395). KeAi Communications Co. <https://doi.org/10.1016/j.aiepr.2023.02.002>
- Widiastuti, I., Azzam, Y. F., Aldiyanto, D. N., Saputra, T. W., & Estriyanto, Y. (2025). Academic community acceptance of recycled plastic products: An analysis of product evaluation and willingness to consume. *Cleaner Waste Systems*, 11. <https://doi.org/10.1016/j.clwas.2025.100280>
- Yan, L., & Cheng, Y. (2026). Circular design education: Material-driven workshops to mitigate plastic pollution. *International Journal of Art & Design Education*, 45(1), 74-89.
- Yang, S., Long, R., Chen, H., & Na, J. (2026). A strategic framework for co-shaping sustainable plastic waste recycling practices through deep learning and social network modeling. *Environmental Impact Assessment Review*, 120. <https://doi.org/10.1016/j.eiar.2026.108436>

- Yao, S., Ghazali, R., Hou, J., & Wang, X. (2024). The Aesthetics Of Sustainability: Incorporating Plastic Recycling Into Art And Design Education. *International Journal of Modern Education*, 6(21), 01–18. <https://doi.org/10.35631/ijmoe.621001>
- Zaky, A. (2019). The affective domain in adult transformative learning: Bridging community experiences with infield environmental education. *Journal of Transformative Education*, 17(3), 210-228.