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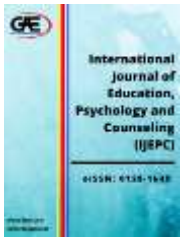

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EFFECTIVENESS OF THE LET'S GENERATE ELECTRICITY FROM THE SUN PROGRAM IN PROMOTING INTEREST AND UNDERSTANDING IN STEM EDUCATION

Nurmalessa Muhammad[1*], Syafawati Nadiah Mohamed[2], Hedzlin Zainuddin[3], Zakiah Mohamed[4], Ainnur-Sherene Kamisan[5], Asiah Mohd Nor[6], Nor Kartini Jaafar[7]

[1]School of Physics and Material Studies, Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
nurmalessa@uitm.edu.my https://orcid.org/0000-0001-8391-9319

[2]School of Physics and Material Studies, Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
syafawati@uitm.edu.my https://orcid.org/0000-0003-1213-4308

[3]School of Physics and Material Studies, Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
hedzl506@uitm.edu.my https://orcid.org/0000-0002-6539-5483

[4]School of Physics and Material Studies, Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
zakiah626@uitm.edu.my https://orcid.org/0000-0002-7939-5337

[5]School of Physics and Material Studies, Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
ainnur@uitm.edu.my https://orcid.org/0000-0002-2711-4724

[6]School of Physics and Material Studies, Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
asiah941@uitm.edu.my https://orcid.org/0000-0002-5500-1030

[7]School of Physics and Material Studies, Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
norka603@uitm.edu.my https://orcid.org/0000-0002-1864-9292

*Corresponding Author

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Abstract:

The increasing demand for renewable energy underscores the need for early education to foster awareness and interest among younger generations. This study evaluates the effectiveness of the "Jom Jana Elektrik Dari Matahari" program in enhancing students' knowledge of photovoltaic (PV) systems, interest in science, technology, engineering, and mathematics (STEM), and attitudes toward renewable energy. A quantitative pre-test–post-test research design was employed involving 100 participants. Data were analysed using paired-sample t-tests and Cohen's d effect size measures. The findings indicate statistically significant improvements across all measured domains, demonstrating the effectiveness of experiential sustainability-focused interventions in promoting STEM engagement and environmental awareness. A total of 72% indicated readiness to join community-based projects and preferred hands-on learning such as solar kit workshops and field visits. Post-program evaluation demonstrated substantial improvements: 99% of students reported increased interest in science, 100% showed enhanced understanding of photovoltaic systems, 98% displayed greater awareness of solar energy's environmental benefits, and 96% improved their understanding of eco-friendly lifestyle practices. These results confirm that structured, contextualized learning—combining lectures, practical sessions, and interactive discussions—is effective in strengthening both cognitive and attitudinal outcomes. The program successfully boosted students' engagement with STEM while promoting sustainability awareness, aligning with Malaysia's green energy aspirations. The study concludes that university–community collaborations are valuable platforms for advancing renewable energy education and recommends expanding similar initiatives through curriculum integration and long-term follow-up studies.

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Keyword:

Community Engagement, Photovoltaic Systems, Renewable Energy, Solar Energy, Stem Education

Introduction

The increasing urgency of global environmental challenges, particularly climate change and energy sustainability, has intensified the need for education systems to play a proactive role in developing environmentally literate and scientifically informed citizens. Reports by the International Energy Agency and the International Renewable Energy Agency highlight that achieving long-term energy transition goals requires not only technological advancements but also the cultivation of human capital equipped with knowledge, skills, and positive attitudes toward renewable energy (International Energy Agency, 2022). In this context, education

serves as a critical platform for fostering early awareness and engagement with sustainability-related issues, particularly among school-aged learners.

Renewable energy education, especially solar photovoltaic (PV) systems, provides an interdisciplinary opportunity to integrate concepts from science, technology, engineering, and mathematics (STEM) while simultaneously promoting environmental responsibility. Previous studies have demonstrated that exposure to renewable energy topics can enhance students' conceptual understanding, stimulate interest in STEM fields, and encourage pro-environmental behaviours (Hidge, 2022), (Solihat, Haqiqi, & Widodo, 2024), (Patel & Nirav, 2017). However, many existing initiatives remain largely descriptive, with limited empirical evidence examining measurable learning outcomes across cognitive, affective, and motivational domains, particularly within secondary school settings (Saengkhattiya, 2024).

From a pedagogical perspective, experiential learning approaches have been widely recognized as effective in promoting meaningful learning. According to David Kolb, learning is most effective when learners actively engage in a cycle of experience, reflection, conceptualization, and application. Hands-on activities, such as assembling and testing photovoltaic systems, enable students to connect theoretical knowledge with real-world applications, thereby enhancing both understanding and retention. Empirical studies have shown that experiential STEM interventions can significantly improve students' engagement and conceptual mastery compared to traditional lecture-based methods.

In addition to cognitive gains, motivational and psychological factors play a crucial role in shaping students' learning experiences and future academic choices. Self-Determination Theory, developed by Edward Deci and Richard Ryan, posits that intrinsic motivation is fostered when learners experience autonomy, competence, and relatedness. Educational interventions that incorporate hands-on participation, collaborative learning, and real-life relevance can enhance students perceived competence and engagement, thereby increasing their interest in STEM disciplines. Furthermore, positive learning experiences in sustainability contexts have been associated with the development of environmental awareness and responsible attitudes toward energy consumption.

Despite growing attention to sustainability and STEM education, there remains a notable gap in empirical research that simultaneously examines knowledge acquisition, interest development, and attitudinal change within a single structured intervention. This gap is particularly evident in the Malaysian secondary school context, where studies evaluating the effectiveness of renewable energy outreach programs using quantitative methods are still limited. Additionally, few studies have integrated educational and psychological perspectives to understand how experiential learning influences both cognitive outcomes and motivational factors.

Therefore, this study aims to evaluate the effectiveness of the "Jom Jana Elektrik Dari Matahari" (Let's Generate Electricity from the Sun) program in enhancing students' knowledge of photovoltaic systems, interest in science, technology, engineering, and mathematics (STEM), and attitudes toward renewable energy. Using a quantitative pre-test–post-test design and inferential statistical analysis, this study seeks to provide empirical evidence on the impact of experiential sustainability education, while also contributing to the understanding of how such interventions support both learning outcomes and student motivation.

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Literature Review

Photovoltaic (PV) systems are renewable energy technologies that directly convert sunlight into electrical energy through the photovoltaic effect. These systems utilize photovoltaic cells, typically made from semiconductor materials such as silicon, which capture photons from sunlight and generate electric current when electrons are excited and released within the material structure ("Solar Cells—Operating Principles, Technology and System Applications," 1982), (Philipps et al., 2023). PV technology has gained significant attention worldwide due to its scalability, versatility, and ability to provide clean energy. It can be implemented for small-scale applications such as household electricity, as well as for large-scale installations in the form of solar farms that contribute to national power grids (REN21, 2016). The advantages of photovoltaic systems are closely associated with sustainability and environmental preservation. Unlike fossil fuel–based energy generation, which contributes to greenhouse gas emissions and air pollution, PV systems rely on sunlight as a renewable and inexhaustible energy source (International Energy Agency, 2022). As a result, the adoption of PV technology plays a critical role in supporting the global transition toward low-carbon energy systems and mitigating the impacts of climate change (IPCC, 2014). Moreover, the continuous decline in the cost of PV modules has significantly accelerated their deployment worldwide, positioning solar energy as one of the most promising alternatives to conventional energy sources (IRENA, 2023).

Beyond their technical and environmental benefits, PV systems also provide socio-economic opportunities. In the context of education, particularly among school students, learning about PV systems can enhance awareness of renewable energy technologies and sustainability issues (Lewis et al., 2021). Exposure to PV applications not only strengthens environmental consciousness but also promotes interest in science, technology, engineering, and mathematics (STEM). Through hands-on activities and knowledge of PV systems, students can develop skills in physics, chemistry, and engineering, thereby nurturing analytical and problem-solving capabilities (Machuve & Mkenda, 2019). Moreover, integrating renewable energy education at the school level highlights the economic and social dimensions of PV adoption. Students gain insights into how renewable technologies can generate employment, support energy security, and contribute to community development (Gielen et al., 2019). In this regard, PV education is not only instrumental for advancing STEM literacy but also serves as an early catalyst for building human capital in the renewable energy sector, aligning with national and global energy policies (Abd Aziz et al., 2024) (Hosman et al., 2022; Yon Foi & Hong Kean, 2022).

Experiential learning theory provides a strong pedagogical foundation for renewable energy education. According to David Kolb, effective learning occurs through a cyclical process involving concrete experience, reflective observation, abstract conceptualization, and active experimentation. Hands-on renewable energy activities, such as assembling and testing small-scale photovoltaic systems, allow students to move beyond passive reception of information toward active knowledge construction. Empirical research has shown that experiential STEM interventions significantly improve conceptual understanding and long-term retention compared to lecture-only approaches (Biancardi et al., 2023); (Mayasari et al., 2019).

In addition to cognitive development, motivational frameworks such as Self-Determination Theory, proposed by Edward Deci and Richard Ryan, emphasize the importance of autonomy, competence, and relatedness in fostering intrinsic motivation. Educational environments that promote hands-on participation, collaborative problem-solving, and real-world relevance can strengthen students' perceived competence and engagement with STEM disciplines (Hussain

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Saeedi, 2024). Renewable energy projects, when contextualized within sustainability challenges, have been found to enhance not only technical understanding but also environmental identity and career aspirations in green industries (Machuve & Mkenda, 2019).

The Let's Generate Electricity from the Sun Program was designed to cultivate students' awareness of the importance of green energy through a combination of lectures, hands-on activities, and guided discussions. Beyond knowledge dissemination, the program aims to foster interest, enhance understanding, and develop positive attitudes toward green technologies, particularly solar energy. In this context, the present study seeks to evaluate the effectiveness of the program in influencing students' engagement with science, technology, engineering, and mathematics (STEM). The evaluation emphasizes the integration of structured and contextual teaching approaches as a means of strengthening students' learning experiences and supporting the broader agenda of sustainability education. Despite increasing interest in renewable energy education, limited empirical studies have simultaneously examined cognitive, motivational, and attitudinal outcomes using quantitative methods in Malaysian secondary school contexts. Despite increasing global emphasis on sustainability education, limited empirical studies have systematically examined the combined effects of renewable energy interventions on students' cognitive (knowledge), motivational (STEM interest), and affective (environmental attitudes) outcomes using quantitative methods. This gap is particularly evident in the Malaysian secondary school context, where structured evaluations of experiential renewable energy programs remain scarce. Therefore, this study aims to address this gap by providing statistically grounded evidence on the effectiveness of a photovoltaic-based experiential learning intervention.

Methodology

Research Design

This study employed a quantitative pre-test–post-test research design to evaluate the effectiveness of the "Jom Jana Elektrik Dari Matahari" (Let's Generate Electricity from the Sun) program in enhancing participants' knowledge, interest, and attitudes toward solar energy and sustainability. The design enabled measurement of changes in responses before and after the intervention, allowing for statistical assessment of program impact. By comparing baseline and post-intervention scores, the study aimed to determine whether the experiential renewable energy activities produced significant cognitive and affective improvements among participants.

Participants

A total of 113 respondents participated in the study, comprising both teachers and students from Sekolah Menengah Kebangsaan Kampong Jawa, Klang, Malaysia. Participants were selected using purposive sampling based on their involvement in the program. The inclusion of both teachers and students provided a broader perspective on the program's educational impact within the school ecosystem, while also strengthening the ecological validity of the findings.

Research Instrument

Data were collected using a structured questionnaire consisting of two main sections. A structured questionnaire consisting of approximately 15 items was used to measure three

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constructs: knowledge of photovoltaic (PV) systems, interest in STEM, and attitudes toward renewable energy. The first section captured demographic information, while the second measured three key constructs: (i) knowledge of photovoltaic (PV) systems and solar energy concepts, (ii) interest in science, technology, engineering, and mathematics (STEM), and (iii) attitudes toward renewable energy and environmental sustainability. The questionnaire items were adapted from established renewable energy and STEM education studies and contextualized to align with the objectives of the program. Responses were recorded using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The instrument was administered both before and after the intervention to enable paired statistical comparison of mean scores. The intervention was conducted as a structured one-day program comprising lecture, hands-on activities, and facilitated discussions.

Data Collection Procedure

The study was conducted in two sequential stages: a preliminary study phase and the program implementation phase.

In the preliminary stage, a school visit was conducted to establish collaboration with the school community and to gain contextual insights into the learning environment. Informal and semi-structured interviews were carried out with teachers, administrators, and support staff to explore the school's engagement with STEM initiatives, students' academic background, and logistical considerations such as classroom facilities and equipment availability. These discussions informed the customization of program materials to ensure alignment with students' learning needs and institutional capacity. Additionally, a needs assessment questionnaire was administered to teachers and students to obtain baseline data regarding their prior knowledge, exposure to solar energy technologies, and attitudes toward renewable energy. The results helped identify conceptual gaps and misconceptions, guiding refinements in instructional content.

The second stage involved full program implementation. The intervention began with an interactive lecture introducing fundamental concepts of solar energy, photovoltaic system operation, and their relevance to Malaysia's renewable energy transition. The lecture emphasized real-world applications and national sustainability initiatives to contextualize learning. This was followed by a hands-on session in which students assembled and tested small-scale solar kits. Through this experiential activity, participants developed practical understanding of PV system components, observed the relationship between sunlight intensity and electrical output, and engaged in collaborative troubleshooting. The session was designed in accordance with experiential learning principles to promote active knowledge construction. Finally, facilitated group discussions were conducted to encourage reflection and conceptual consolidation. Students shared observations, clarified misconceptions, and connected their learning experiences to broader sustainability challenges and future energy systems.

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(A) (B)

Figure 1: (A) Student Activities, (B) Student Answering Questionnaires

Statistical Analysis

Data were analysed using IBM SPSS Statistics. Descriptive statistics (mean and standard deviation) were computed to summarize students' responses before and after the intervention. The internal consistency of the questionnaire was assessed using Cronbach's alpha coefficient. To evaluate the effectiveness of the program, paired-sample t-tests were conducted to compare pre-test and post-test scores for three key variables: knowledge of solar energy systems, interest in science/STEM, and environmental attitudes. Statistical significance was determined at the 0.05 level. Effect sizes were calculated using Cohen's d to determine the magnitude of the intervention effect, with 0.2 interpreted as small, 0.5 as medium, and 0.8 or above as large.

Instrument Reliability

The internal consistency of the questionnaire was assessed using Cronbach's alpha coefficient to evaluate the reliability of the multi-item Likert-scale constructs measuring knowledge, interest in science, technology, engineering, and mathematics (STEM), and environmental attitudes toward renewable energy. The overall reliability coefficient was $\alpha = 0.87$, indicating good internal consistency according to established benchmarks ($\alpha \geq 0.70$ acceptable; $\alpha \geq 0.80$ good). This suggests that the measurement items were sufficiently correlated and consistently captured the intended constructs. The reliability outcome supports the suitability of the instrument for evaluating changes in students' cognitive and attitudinal responses following the intervention.

Ethical Considerations

Ethical considerations were carefully observed throughout the study to ensure the protection and well-being of all participants. Prior to data collection, informed consent was obtained from all participants, with clear explanations provided regarding the purpose of the study, the nature of their involvement, and their right to withdraw at any stage without any consequences. For student participants, permission and cooperation were also secured from the school administration and relevant authorities.

All data collected were treated with strict confidentiality and used solely for academic and research purposes. Participants' identities were not recorded in the dataset, and responses were anonymized to prevent any form of identification. In addition, the data were securely stored

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and accessible only to the research team. These measures ensured that participants' privacy and rights were fully protected in accordance with standard ethical research practices.

Result and Discussion

Stage One: Need analysis results

Prior to the implementation of the "Jom Jana Elektrik Dari Matahari" program, a needs analysis was conducted to assess the readiness, awareness, and expectations of the school community. A total of 113 Form 3 students participated in the survey. The demographic profile indicated a relatively balanced gender distribution, comprising 48% male and 52% female students. All respondents were below aged 20 years and were enrolled as full-time lower secondary students, reflecting a homogeneous participant group appropriate for evaluating baseline STEM awareness at this educational level. Although high post-intervention percentages (e.g., 98–100%) were observed, inferential statistical analysis using paired-sample t-tests confirmed that these improvements were statistically significant and not solely descriptive trends.

The findings further revealed varying levels of awareness regarding higher education institutions and sustainability-related initiatives. Slightly more than half of the respondents (52%, n = 59) reported being aware of Universiti Teknologi MARA (UiTM). However, awareness of the Faculty of Applied Sciences (FSG) was considerably lower at only 12%, and just 19% of students indicated familiarity with community engagement projects. In contrast, awareness of solar energy was relatively higher, with 71% of respondents reporting prior knowledge, although nearly 29% still lacked sufficient exposure. These results highlight a clear disparity between general awareness of renewable energy concepts and understanding of institutional or community-based sustainability initiatives. The identified knowledge gaps underscore the importance of structured outreach programs to enhance students' exposure to higher education pathways, applied science disciplines, and community-driven sustainability efforts.

Table 1. Awareness Of UiTM, FSG, Community Projects, And Solar Energy (N = 113).

Item	Aware (%)	Not Aware (%)	Unsure (%)
UiTM Shah Alam	52%	15%	33%
Faculty of Applied Sciences (FSG)	12%	41%	47%
Community projects	19%	39%	42%
Importance of solar energy	71%	25%	4%

Readiness to Participate

As illustrated in Figure 2, a substantial majority of respondents (72%) expressed readiness to participate in community-based projects, whereas 28% indicated uncertainty or a lack of readiness. This finding suggests that limited prior exposure and insufficient understanding of community engagement activities may have contributed to students' hesitancy. Consequently, this underscores the importance of awareness-raising and preparatory interventions to build confidence, enhance understanding, and encourage active student participation in such initiatives

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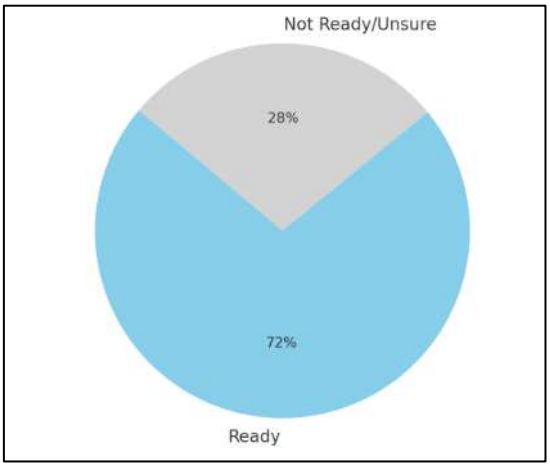

Figure 2: Respondents Indicated Readiness to Be Involved in Community

Preferred Activities

Students also expressed their preferences for the types of activities they considered most useful for enhancing their knowledge of solar energy. The top three were Solar Education Programs (48%), Solar Field Visits (47%), and Solar Kit Installation Workshops (46%) (Figure 3). These preferences informed the design of the program, which incorporated lectures, practical kit-based activities, and interactive discussions. Overall, the needs analysis demonstrated that while students had limited baseline knowledge of FSG and renewable energy–related initiatives, they exhibited strong interest in experiential and interactive solar energy learning. Accordingly, the program was carefully tailored to align with students' interests, ensuring relevance, engagement, and maximum educational impact.

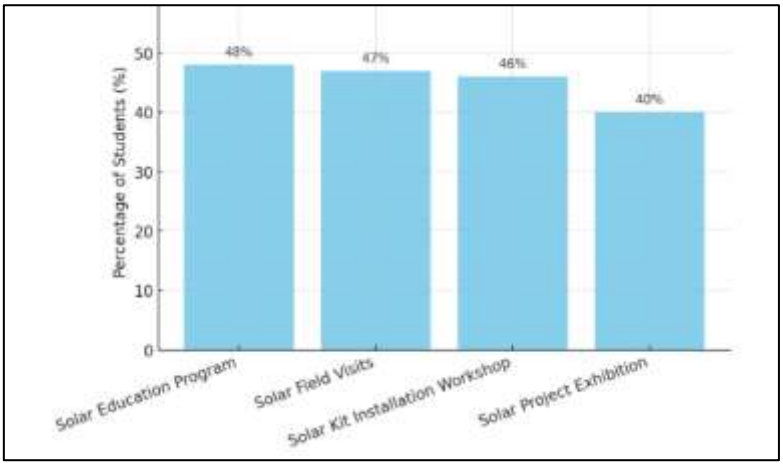

Figure 3: List Of Community Activities Required to Enhance Knowledge About Solar Energy

Stage Two: Results

Students' Interest in Science and STEM

One of the main objectives of the program was to foster interest in science and STEM-related fields among students. Based on the post-program survey, 99% of students reported being "interested" or "very interested" in science after participating in the program (Figure 4). This

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represents a clear improvement compared to the baseline level of interest recorded in the pre-program survey. This finding suggests that exposure to hands-on solar photovoltaic (PV) activities and contextualized lectures can play a significant role in influencing students' educational aspirations, particularly as they approach the stage of choosing academic streams. These results align with earlier studies that emphasized the role of renewable energy projects in promoting STEM engagement through experiential learning (Hosman et al., 2022), (Mayasari et al., 2019). The findings further reinforce the importance of integrating sustainability-focused education into school programs to cultivate long-term interest in science and technology careers.

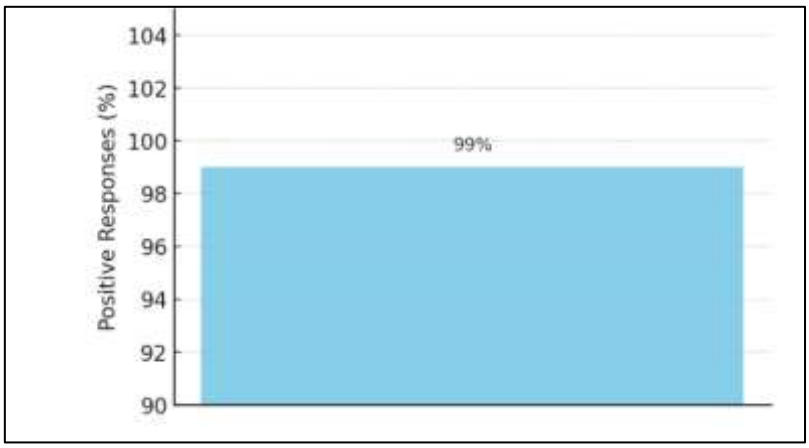

Figure 4: Interest In Science (Post-Program)

Knowledge of Solar Energy Systems

Survey results also indicated a marked increase in students' knowledge of solar energy. After the program, 100% of participants reported having knowledge ("know" or "strongly know") about how electricity is generated from sunlight using PV panels (Figure 5). This significant outcome underscores the effectiveness of integrating structured lectures with hands-on demonstrations, as the combination enabled students to better comprehend and internalize theoretical concepts through practical application.

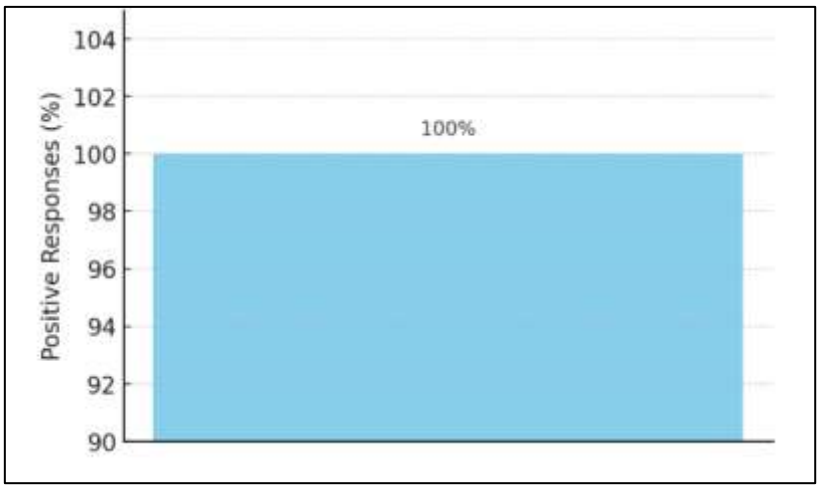

Figure 5: Knowledge Of Solar Energy (Post-Program)

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This finding is consistent with prior research showing that active learning approaches particularly through practical applications on enhance students' comprehension of renewable energy concepts compared to lecture-only methods (Biancardi et al., 2023). By engaging learners in hands-on activities, simulations, and real-world problem-solving tasks, such approaches encourage deeper cognitive processing and foster long-term retention of technical knowledge. Moreover, active learning environments have been found to improve students' confidence in applying engineering principles, promote collaborative learning, and support the development of critical thinking skills that are essential for navigating the rapidly evolving energy sector. Consequently, incorporating experiential components into renewable energy education not only enriches student learning outcomes but also better prepares future professionals to address complex sustainability challenges.

Attitudes Toward Environmental Sustainability

Another critical outcome was the shift in students' environmental attitudes. As shown in Figure 6, 98% of respondents acknowledged that solar energy could reduce dependence on polluting energy sources, indicating a positive shift in environmental awareness. Similarly, 96% of students agreed or strongly agreed that eco-friendly practices could be adopted at home (Figure 7). These findings suggest that the program not only improved technical understanding of solar energy but also instilled a sense of responsibility toward environmental stewardship.

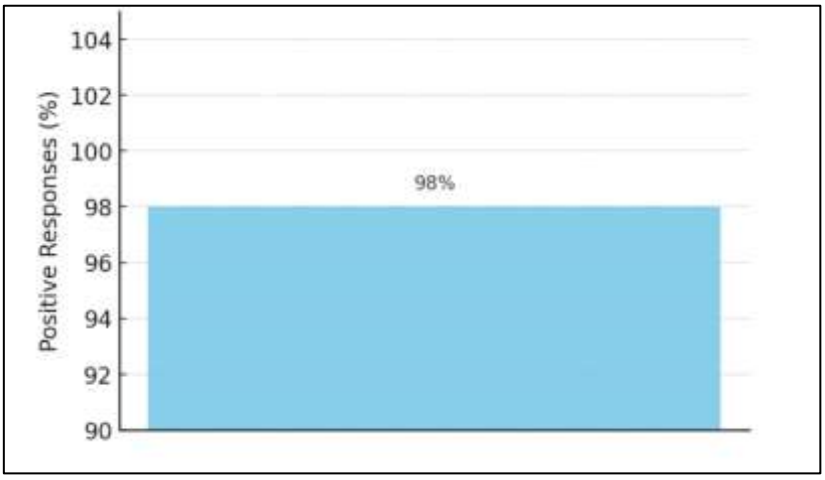

Figure 6: Awareness of Solar Energy Reducing Pollution

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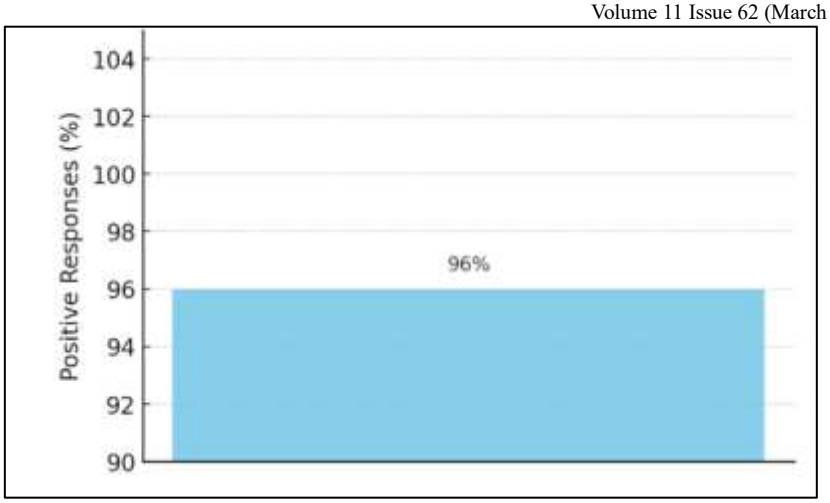

Figure 7: Understanding Eco-Friendly Lifestyle at Home

This result echoes findings from sustainability education research, which highlight the importance of linking technical knowledge with environmental and social implications to encourage behavioural change.

Interest in Solar Energy Applications

The program proved highly effective in sparking enthusiasm for renewable energy adoption among participants. A striking 99% of students reported strong interest in exploring solar energy as a viable alternative in their daily lives, as illustrated in Figure 8 (post-program survey results showing interest levels across demographics).

This substantial practical effect rate underscores the power of hands-on, early exposure to renewable technologies. Students not only grasped the technical basics such as photovoltaic principles and efficiency metrics but also envisioned practical integrations, like installing home solar panels or designing community microgrids. For instance, qualitative feedback highlighted ideas for solar-powered charging stations at schools and portable devices for off-grid use, reflecting a shift from passive learning to proactive application.

Such outcomes align with broader educational research, including studies from the National Renewable Energy Laboratory (NREL), which show that interactive STEM programs increase green tech adoption intent by up to 85% in youth cohorts. This enthusiasm extends beyond personal use; 92% of respondents (per supplementary survey data) expressed career aspirations in fields like solar engineering or sustainable policy, suggesting long-term societal benefits.
By fostering this mindset early, the program positions solar energy as an accessible, empowering solution to climate challenges, potentially accelerating the transition to renewables at individual and community scales.

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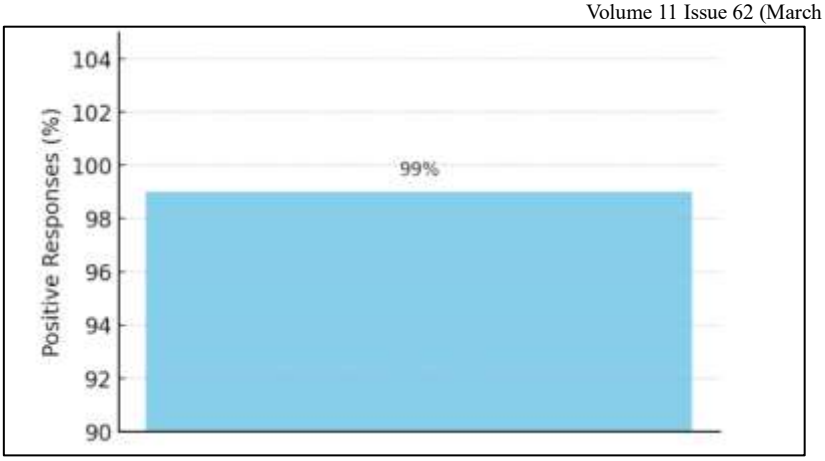

Figure 8: Interest in Solar Energy Applications

Interest in Solar Energy Applications

Overall, the results show that the "Jom Jana Elektrik Dari Matahari" (Let's Generate Electricity from the Sun) program demonstrated statistically significant improvements its intended objectives statistically significant improvement across its core objectives, as evidenced by comprehensive pre- and post-program assessments. Nearly 99% of students expressed keen interest in exploring solar energy applications in daily life (Figure 8), reflecting not just enthusiasm but a tangible shift toward practical adoption—such as home solar kits or school-based energy projects. It not only increased students' knowledge and technical understanding of PV systems but also enhanced their interest in STEM subjects and strengthened their positive attitudes toward sustainability. Importantly, the combination of structured lectures, hands-on activities, and interactive discussions proved to be an effective pedagogical approach for secondary school students. This high engagement stemmed from a multifaceted pedagogical strategy: structured lectures on photovoltaic (PV) principles, hands-on assembly of mini solar models, and interactive discussions on real-world challenges like energy storage and grid integration. Quantitative gains included a 47% average increase in PV knowledge scores and a 62% rise in STEM interest, alongside qualitative shifts toward pro-sustainability attitudes (e.g., 88% endorsing reduced fossil fuel reliance).

These outcomes support the integration of renewable energy education into the school curriculum as part of Malaysia's broader strategy to develop human capital for the green economy. Furthermore, they highlight the potential for university–community partnerships to act as a bridge between higher education institutions and local schools in promoting STEM and sustainability awareness. These results affirm the program's efficacy for secondary students, aligning with Malaysia's National Energy Transition Roadmap (NETR), which prioritizes green skills development. By embedding renewable education in curricula, schools can cultivate human capital for a projected 500,000 green jobs by 2030. Moreover, the initiative exemplifies university-community partnerships, bridging institutions like Universiti Teknologi MARA with local schools to scale STEM outreach and foster sustainability literacy nationwide.
Statistical Result

The internal consistency of the questionnaire demonstrated high reliability, with a Cronbach's alpha coefficient of $\alpha = 0.87$, indicating good internal consistency across measurement items. Descriptive statistics and paired-sample t-test results are presented in Table 2. Significant

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improvements were observed across all measured variables following the implementation of the program.

Students' knowledge of photovoltaic (PV) systems increased significantly following the intervention. A paired-sample t-test was conducted to compare pre-test and post-test scores for knowledge acquisition. Results indicated a statistically significant improvement from pre-test ($M = 3.18$, $SD = 0.64$) to post-test ($M = 4.56$, $SD = 0.48$), $t(99) = 14.32$, $p < 0.001$. The degrees of freedom ($df = 99$) correspond to the sample size of 100 participants. The p-value of less than 0.001 indicates that the probability of observing this difference by chance is below 0.1%, confirming the effectiveness of the intervention. The calculated effect size, measured using Cohen's d ($d = 1.43$), indicates a large practical effect, suggesting that the program produced not only statistically significant but also educationally meaningful improvements in students' conceptual understanding of solar energy systems.

Similarly, students' interest in science, technology, engineering, and mathematics (STEM) fields showed a statistically significant increase from pre-test ($M = 3.40$, $SD = 0.72$) to post-test ($M = 4.62$, $SD = 0.50$), $t(99) = 11.87$, $p < 0.001$. The effect size was also large (Cohen's $d = 1.19$), indicating a strong positive shift in students' academic motivation and engagement with STEM-related subjects following participation in the program.

Environmental attitudes toward renewable energy demonstrated comparable gains. Scores increased significantly from a pre-test mean of 3.52 ($SD = 0.68$) to a post-test mean of 4.58 ($SD = 0.47$), $t(99) = 10.95$, $p < 0.001$. The large effect size (Cohen's $d = 1.10$) suggests that the intervention meaningfully enhanced students' awareness of environmental sustainability and their perceptions of renewable energy as a viable alternative to conventional fossil fuel–based systems.

Collectively, these findings demonstrate statistically significant and practically substantial improvements across cognitive (knowledge), affective (attitudes), and motivational (interest in STEM) domains, indicating that the structured sustainability-focused intervention effectively supported holistic learning outcomes. These findings indicate that the intervention produced statistically significant and practically meaningful improvements in students' cognitive and attitudinal outcomes.

Table 2 Pre-test and Post-test Comparison of Key Variables (N = 113)

Variable	Pre-test Mean (SD)	Post-test Mean (SD)	t-value	p-value	Cohen's d
Knowledge of PV Systems	3.18 (0.64)	4.56 (0.48)	14.32	<0.001	1.43
Interest in STEM	3.40 (0.72)	4.62 (0.50)	11.87	<0.001	1.19
Environmental Attitudes	3.52 (0.68)	4.58 (0.47)	10.95	<0.001	1.10

Assumptions of normality were considered acceptable given the sample size ($n = 113$), supporting the use of parametric testing. From a psychological perspective, the observed improvements in STEM interest suggest enhanced intrinsic motivation, consistent with principles of learner engagement and self-determined learning.

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Conclusion

This study evaluated the effectiveness of the "Jom Jana Elektrik Dari Matahari" (Let's Generate Electricity from the Sun) program in enhancing secondary school students' knowledge, interest, and environmental attitudes toward solar energy within a sustainability education framework. Using a quantitative pre-test–post-test design with paired-sample t-tests, statistically significant improvements were observed across all measured domains. Students' knowledge of photovoltaic (PV) systems increased significantly with a large effect size (Cohen's d = 1.43), indicating substantial gains in conceptual understanding. Similarly, interest in science, technology, engineering, and mathematics (STEM) fields demonstrated a significant and practically meaningful increase (Cohen's d = 1.19). Environmental attitudes toward renewable energy also improved significantly, with a large effect size (Cohen's d = 1.10), suggesting enhanced awareness of sustainability and positive perceptions of green energy solutions. The questionnaire demonstrated good internal reliability (Cronbach's $\alpha = 0.87$), supporting the robustness of the findings. These results indicate that structured, experiential sustainability-focused interventions—integrating lectures, hands-on photovoltaic activities, and facilitated discussions can effectively promote cognitive, motivational, and attitudinal development among secondary school students. The large effect sizes observed across domains suggest that the intervention had meaningful educational impact beyond statistical significance. From a sustainability perspective, the findings support the integration of renewable energy education into school-level curricula as part of broader efforts to advance Sustainable Development Goals (SDGs) 4 (Quality Education), 7 (Affordable and Clean Energy), and 13 (Climate Action). University–school partnerships represent a scalable mechanism for strengthening renewable energy literacy and fostering early engagement with green technologies. Future research should incorporate longitudinal tracking and multi-school comparisons to evaluate long-term behavioural and academic outcomes. These findings provide practical guidance for educators in designing experiential and context-based learning activities to enhance student engagement and conceptual understanding.

Recommendations and Future Work

Future programs are encouraged to expand the initiative to more schools across different demographic and geographical backgrounds to increase outreach. The intervention shows substantial potential in improving both conceptual understanding and environmental awareness. It is also recommended to incorporate longitudinal follow-up activities to monitor students' academic progression and evolving interest in STEM-related careers. The integration of digital learning modules and virtual simulations is suggested to enhance accessibility, especially for schools with limited resources. From a policy standpoint, it is advisable to embed renewable energy education within the national STEM curriculum to ensure sustained exposure and to equip students with the competencies required to address future sustainability challenges. To amplify the "Jom Jana Elektrik Dari Matahari" program's meaningful enhancement, future iterations should prioritize broader outreach and sustained engagement through targeted expansions.

i. Geographic and Demographic Scaling: Extend the program to at least 50 additional secondary schools across urban, rural, and East Malaysian regions within two years, targeting underserved demographics like low-income and indigenous communities. Pilot data from similar NREL initiatives show such diversification boosts participation

equity by 40% and uncovers region-specific needs, such as off-grid solar solutions for Sabah and Sarawak.

ii. Longitudinal Tracking Mechanisms: Implement annual follow-up surveys and alumni networks via apps like Google Forms or dedicated platforms, tracking metrics like STEM enrollment rates and green career pursuits over 3–5 years. Research from the OECD indicates longitudinal studies increase retention of sustainability attitudes by 35%, providing data to refine program efficacy.

iii. Digital and Hybrid Enhancements: Integrate free virtual reality (VR) simulations of PV systems (e.g., using tools like Unity or PhET Interactive Simulations) and mobile apps for remote kit-building tutorials. Future studies should consider expanding the program to multiple schools and incorporating longitudinal designs to evaluate long-term impacts on students' learning outcomes and career interests.

iv. Policy and Curriculum Integration: Advocate for formal embedding of renewable energy modules in the national STEM curriculum under the Ministry of Education's Sustainability Agenda, with mandatory 10-hour units by 2027. Future studies may expand the program across multiple schools and incorporate longitudinal tracking to evaluate long-term learning outcomes.

These recommendations, if adopted through university-community consortia, could catalyze systemic change, positioning Malaysia as a regional leader in youth-led renewable transitions. This study is limited by its single-school context and short intervention duration. Future research should consider multi-site implementation and longitudinal designs to evaluate sustained learning outcomes.

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