Enhancing STEM Interest and Science Stream Enrolment Among B40 Students in Rural Pahang, Malaysia through the STEMA Garden Module

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Received: 18 June 2025; Accepted: 24 June 2025

Abstract
STEM education is essential for future career readiness, yet rural B40 students in Pahang, Malaysia face challenges in accessing engaging and practical learning opportunities. This case study examines the STEMA Garden Module, an initiative designed to increase students' awareness of agriculture’s economic value, impart agricultural science and entrepreneurship knowledge, and enhance STEM and art interest through hands-on agricultural activities. Implemented at SMK Sg Lembing, Kuantan, the program engaged 82 Form 1 students, 7 teachers, and 17 university mentors, integrating an IoT-powered fertigation system, plant management, and agribusiness training. A mixed-methods approach was used, including pre- and post-program surveys and teacher interviews. Findings revealed improvements were recorded in general interest in STEM education (Q1, $p = 0.0011$), the intention to further one’s studies in STEM (Q2, $p = 0.0336$), excitement and readiness to engage in hands-on activities (Q5, $p = 0.0017$), interest in learning how to think creatively to solve real-life problems (Q11, $p = 0.0169$), and interest in learning science and entrepreneurship to become an agropreneur (Q12, $p = 0.0093$). The thematic analysis of teacher reflections highlighted technology-driven learning, project-based teaching, improved student engagement, entrepreneurial mindset development, and school-wide STEM transformation as key outcomes. Students gained practical exposure to agricultural technology and entrepreneurship, leading to their first harvest of 8.127 kg of chili, generating RM229.00 in revenue. Despite challenges such as fungal infections and WiFi interruptions affecting the IoT fertigation system, students demonstrated adaptability and problem-solving skills. This study highlights the potential of agriculture-based STEM education in fostering engagement, interdisciplinary learning, and real-world applications among rural area students. The STEMA Garden Module serves as a scalable model for integrating STEM with agriculture and entrepreneurship, making STEM education more accessible and relevant. Future implementations should explore long-term impact assessment and technological advancements to further enhance learning outcomes and STEM career aspirations.

Keywords: STEM education, STEM garden, agriculture, entrepreneurship, PBL

Introduction

STEM education has been recognized as a key driver of national development, equipping students with the knowledge and skills necessary for innovation, economic growth, and global competitiveness (Shahali *et al.,* 2017). However, in rural Malaysia, students—particularly those from B40 socioeconomic backgrounds—often face limited exposure to engaging and practical STEM learning experiences, contributing to low interest and enrolment in science streams (Ali *et al.,* 2018; Anuar, 2021). To address this gap, integrating agriculture-based activities into STEM education has emerged as a promising strategy to make STEM learning more relevant, hands-on, and aligned with rural students' lived experiences (Stubbs & Myers, 2015; Ridgeway & Brown, 2018).

Agriculture provides an interdisciplinary platform for STEM learning, connecting concepts from biology, chemistry, physics, engineering, and technology with real-world applications (McNeill *et al*., 2020). Programs such as AgLIT (Agricultural Literacy Through Innovative Technology) have demonstrated the efficacy of project-based agricultural STEM education in enhancing students' scientific literacy and problem-solving skills (Vallera & Bodzin, 2020). Additionally, agriculture-based STEM initiatives promote entrepreneurship, sustainability awareness, and workforce readiness, making them particularly beneficial for students in rural settings where agriculture remains a significant economic sector (Chumbley *et al.,* 2015).

Recognizing the potential of agriculture to spark STEM interest, the STEMA Garden Module was introduced as an innovative educational approach to bridge the gap between STEM education and real-world agricultural applications. This module aims to (i) raise students' awareness of the value and importance of agriculture to the national economy, (ii) impart knowledge of agricultural science and entrepreneurship, and (iii) increase students' interest in STEM and the arts. By integrating hands-on gardening activities with STEM principles, this approach seeks to enhance engagement, motivation, and conceptual understanding among B40 students in rural Malaysia, ultimately encouraging them to pursue science-related academic and career pathways.

Existing studies on informal STEM learning highlight the importance of contextually relevant, experiential learning activities in fostering student interest and retention in STEM fields (Shamuganathan, 2023; Saat & Fadzil, 2022). The STEMA Garden Module aligns with these principles by immersing students in real-world problem-solving scenarios, allowing them to see the direct impact of STEM in their daily lives. This case study explores the effectiveness of the STEMA Garden Module in increasing STEM interest and science stream enrolment among rural B40 students, contributing to the broader discourse on innovative STEM pedagogies tailored to marginalized communities.

Methodology

This study employs a case study approach to investigate the effectiveness of the STEMA Garden Module in increasing STEM interest among B40 students in rural Malaysia. The study was conducted at SMK Sg Lembing, Kuantan, involving 82 Form 1 students from diverse ethnic backgrounds (Malay, Indian, Chinese, and Orang Asli). The module was implemented over six months (May–November 2024), incorporating hands-on agricultural activities, STEM integration, and entrepreneurship training to provide a holistic learning experience.

The project began with a preparatory phase to ensure smooth execution. Several coordination meetings throughout May 2024 brought together teachers, facilitators, and stakeholders, including National STEM Association (NSA) representatives and universities mentors, to discuss the project implementation. This was followed by a site visit on 25 June 2024, where the team assessed the school's available land and resources for setting up the STEMA Garden. Once the groundwork was completed, students participated in a STEMA Garden Design Workshop on 3 July 2024**,** where they learned about vegetable and fruit varieties, the basic needs of plants, garden layout planning and sustainable agriculture techniques. The workshop encouraged students to apply STEM principles in designing their learning space.

Following the design phase, the fertigation system installation took place from 19 to 21 July 2024**,** introducing students to modern agricultural technology. To enhance their understanding, a fertigation workshop on 29 July 2024 provided hands-on training in plant nutrition, irrigation techniques, and soil health management. This phase allowed students to integrate scientific knowledge with practical applications, fostering an appreciation for STEM in real-world contexts.

After the infrastructure was in place, students engaged in continuous plant management and care activities. They monitored plant growth, recorded observations, and analysed scientific data, reinforcing their learning in agricultural science. To introduce the entrepreneurial aspect of the program, an Agropreneur Workshop was conducted on 28 October 2024 , equipping students with knowledge on agribusiness, financial literacy, and marketing strategies. This session aimed to develop students' entrepreneurial mindset by teaching them the fundamentals of commercializing agricultural products.

The final phase of the project focused on harvesting, packaging, and selling activities on 30 November 2024**.** Students actively participated in the harvesting process, learning about food production, supply chain logistics, and sustainable farming practices. They were also responsible for marketing and selling their produce, applying the knowledge gained throughout the program. This hands-on experience helped them develop problem-solving, teamwork, and financial management skills, further reinforcing the integration of STEM education with real-world applications.

To evaluate the effectiveness of the STEMA Garden Module, a mixed-methods approach was adopted. Pre- and post-program surveys were conducted to measure changes in students' STEM interest and their willingness to enrol in the science stream. Quantitative data was analysed using SPSS version 26.0 to assess participation rates and the impact of the program on students' confidence in STEM-related subjects. Additionally, qualitative data was collected through teacher interviews**,** providing insights into students' learning experiences, motivation, and engagement throughout the program.

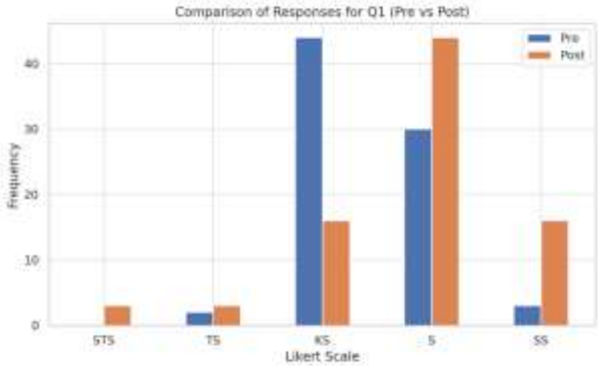
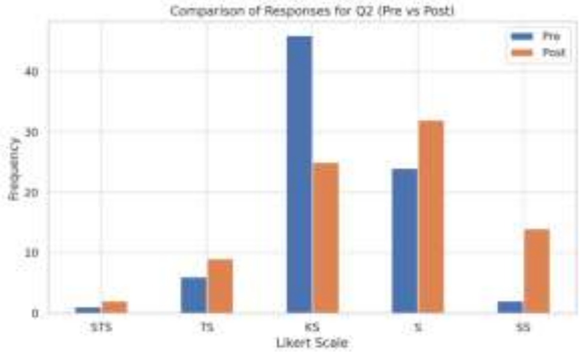
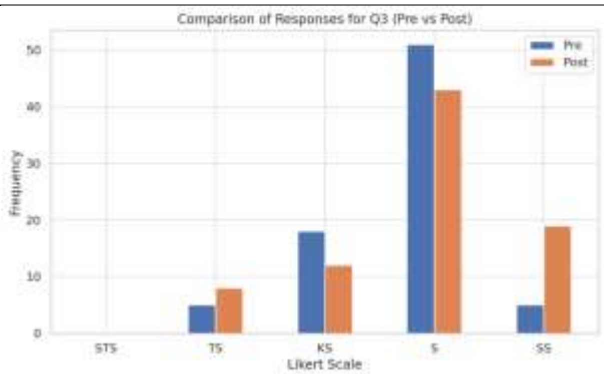
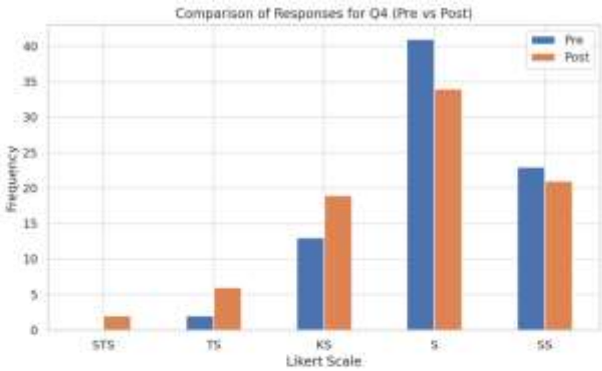
Through this structured implementation, the STEMA Garden Module aims to foster a greater interest in STEM fields among B40 students**,** particularly by making science learning more engaging and relevant to their daily lives. The project also seeks to develop students' technical skills in agriculture, problem-solving abilities, and entrepreneurial competencies, ultimately preparing them for future careers in STEM-related fields. By integrating STEM education with agricultural activities, this study highlights the potential of innovative pedagogical approaches to increase STEM interest and science stream enrolment among rural students in Malaysia.

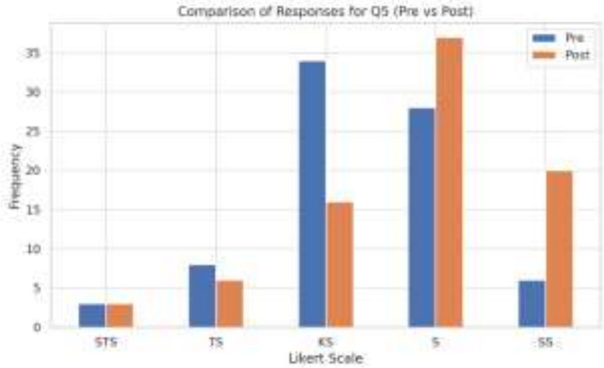
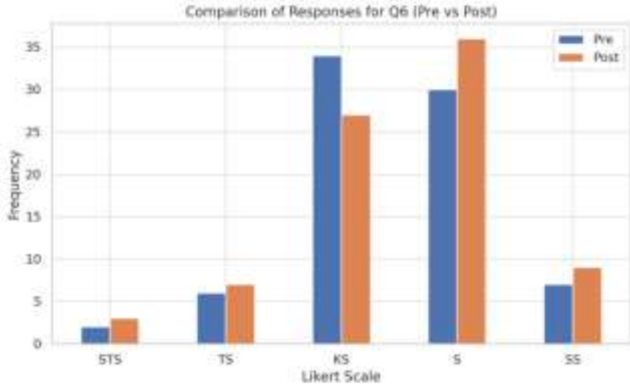
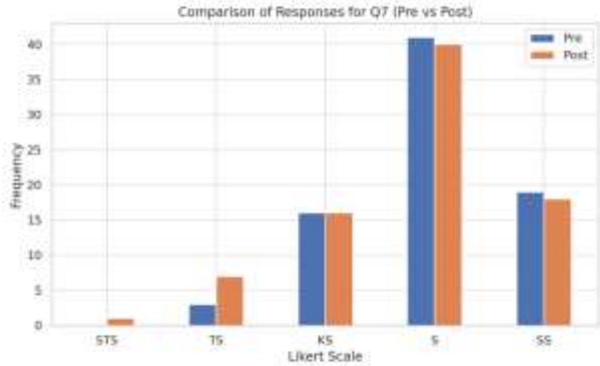
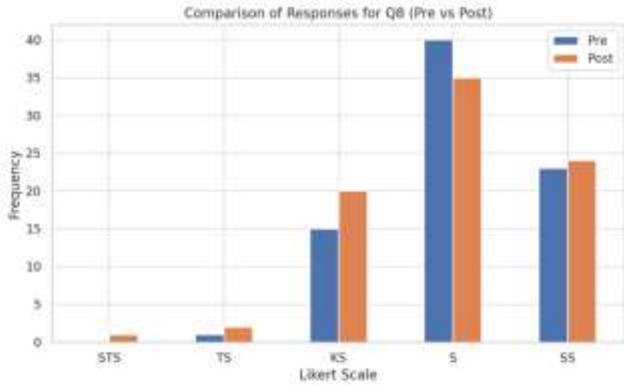
Results and Discussion

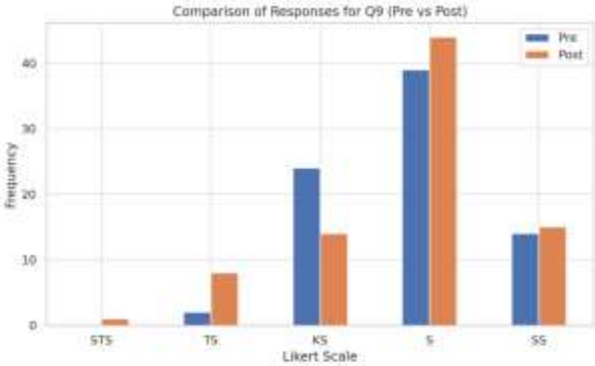
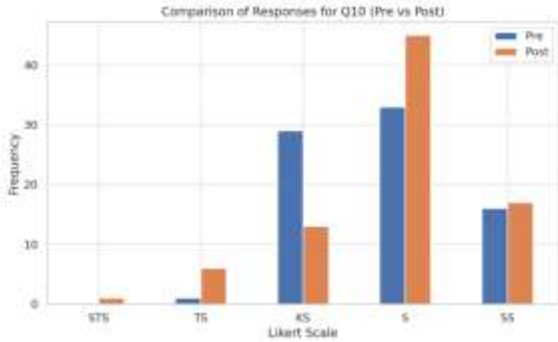
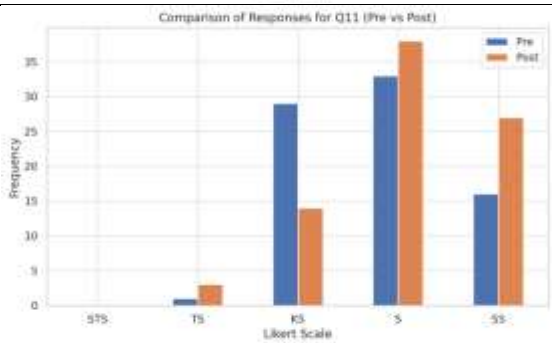
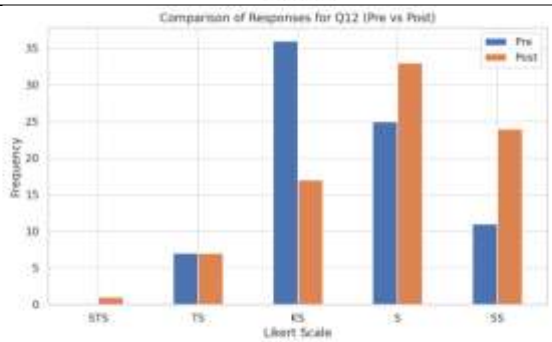
The implementation of the STEMA Garden Module yielded significant positive outcomes in students' interest in STEM education, teacher engagement, mentorship involvement, and agricultural productivity, despite facing challenges such as fungal infections affecting chili plants and intermittent WiFi interruptions impacting fertigation system operations. One of the most significant findings was the 31% increase in students' interest in STEM education, as demonstrated by pre- and post-program surveys. Initially, only 41% (n=34) of students expressed interest in STEM-related subjects, but after participating in the module, this number increased significantly to 73**%** (n=60 students, *p*-value=0.0011) demonstrating the effectiveness of agriculture-based STEM learning in making science and technology more engaging and relevant. At the same time, the percentage of students not interested in STEM declined from 59% (n=48 students) to 27% (n=22 students), highlighting the impact of experiential, real-world applications in sparking students' enthusiasm for STEM disciplines.

Visual comparison using bar charts in Table 1 further supports this upward trend in student interest, revealing a noticeable shift from neutral or negative responses (e.g., "Kurang Setuju" or "Tidak Setuju") toward more positive responses (e.g., "Setuju" and "Sangat Setuju") across the majority of survey items. This positive change was particularly evident in items related to overall interest in STEM, enthusiasm for hands-on activities, and aspirations to pursue further education in STEM-related fields. Statistical analysis using the Wilcoxon signed-rank test confirmed that several of these changes were statistically significant. Specifically, notable improvements were recorded in general interest in STEM education (Q1, p = 0.0011), the intention to further one's studies in STEM (Q2, p = 0.0336), excitement and readiness to engage in hands-on activities (Q5, p = 0.0017), interest in learning how to think creatively to solve real-life problems (Q11, p = 0.0169), and interest in learning science and entrepreneurship to become an agropreneur (Q12, p = 0.0093). These findings reinforce the effectiveness of the STEMA Garden Module in enhancing students' engagement with STEM, particularly through contextual, experiential learning that integrates real-world challenges with scientific exploration. While other items, such as enjoyment of STEM activities (Q3) and eagerness for science projects (Q4), also showed positive trends, they did not reach statistical significance, indicating potential areas for deeper pedagogical emphasis in future iterations of the program. Overall, the module's impact on student interest is both quantifiable and meaningful, suggesting that agriculture-based STEM education can serve as a powerful catalyst for cultivating sustained student motivation and interest in science and technology.

Table 1: Comparison of responses to 12 questionnaire items (Q1 to Q12) administered to 82 students before and after the STEM program.

Code	Item	Bar Chart	*p*-value[1]
Q1	I am very interested in STEM education.		0.0011*
Q2	I am very interested in furthering my studies in the field of STEM.		0.0336*
Q3	I enjoy participating in STEM learning activities.		0.1385
Q4	I am excited and eager to carry out science projects.		0.1131

Q5	I am excited and eager to engage in hands-on/practical activities.		0.0017*
Q6	I am interested in learning STEM concepts through agricultural applications.		0.6061
Q7	I am very interested in expanding my knowledge in plant science.		0.3391
Q8	I am very interested in expanding my knowledge in technology.		0.4666

Q9	I am very interested in enhancing my creativity and innovation in science.		0.7869
Q10	I am very interested in understanding scientific applications to solve environmental problems and challenges.		0.6171
Q11	I want to learn how to think creatively to solve real-life problems.		0.0169*
Q12	I am very interested in learning science and entrepreneurship to become an agropreneur.		0.0093*

[1]Wilcoxon Signed Rank Test. * = *indicates a statistically significant result with a p-value less than 0.05. STS= Sangat Tak Setuju/Strongly Disagree, TS= Tak Setuju/Disagree, KS= Kurang Setuju/Slightly Disagree, S= Setuju/Agree, SS= Sangat Setuju/Strongly Agree*

Beyond student engagement, the program significantly contributed to capacity building among educators and university mentors. A total of 82 Form 1 students and 7 teachers from Technology Design, Science, and Mathematics disciplines actively participated in training sessions, workshops, and agricultural activities. Additionally, 17 university mentors from IIUM, UPM, and Taylor's University provided guidance and mentorship, fostering a collaborative learning environment that strengthened both student learning and teacher professional development. By integrating IoT technology into the fertigation system, the project also introduced students and teachers to smart agriculture concepts, showcasing the practical applications of technology in optimizing agricultural processes. The IoT-based fertigation system was programmed to automate the fertiliser distribution schedule, reducing manual labour while improving efficiency. However, occasional WiFi disruptions posed challenges, requiring adaptive problem-solving from students and teachers, reinforcing critical thinking skills in technology management.

The STEMA Garden also emerged as a valuable outdoor learning space, transforming traditional teaching methods by providing students with a hands-on, problem-solving environment to explore STEM concepts in an interdisciplinary manner. The integration of technology design, agricultural science, and entrepreneurship elements contributed to a more experiential learning experience, aligning with previous studies that emphasize the role of agriculture as a meaningful context for STEM education, particularly in rural settings where traditional STEM instruction may lack relevance (McNeill *et al.,* 2020; Stubbs & Myers, 2015).

In terms of agricultural productivity and entrepreneurial learning, the first harvest yielded 8.127 kg of chili, generating a total revenue of RM229.00. This successful first harvesting session (Figure 1 and 2) was achieved despite facing fungal infections affecting chili plants, which required students to apply scientific principles in pest and disease management. The sale of the first batch of produce provided students with hands-on experience in agribusiness, allowing them to apply knowledge in financial literacy, marketing strategies, and supply chain logistics. This reinforces the importance of integrating STEM education with entrepreneurship, enabling students to see the direct economic and social impact of STEM applications.

These findings suggest that agriculture-based STEM education, particularly with the integration of IoT and entrepreneurship, has the potential to significantly enhance student engagement, teacher participation, and real-world problem-solving skills. The incorporation of smart agriculture tools not only modernized traditional farming methods but also exposed students to the future of precision agriculture and agritech innovations. However, challenges such as technical disruptions and crop disease management highlight the need for adaptive strategies and continuous improvements in future implementations. Expanding this model to other rural schools and conducting longitudinal studies to assess the long-term impact on STEM career aspirations and academic performance will be crucial in evaluating its scalability and sustainability.

Figure 1: Students performing their duties by harvesting chillies and inspecting the plants for signs of infection.

Figure 2: Two baskets of freshly harvested chillies collected by students during the harvesting activity.

The STEMA Garden Program has led to significant transformations in STEM learning, student engagement, instructional leadership, and school-wide initiatives, as summarized in Table 2. Findings from interviews with teachers reveal that the integration of IoT-powered fertigation systems and smart agricultural technologies provided educators and students with hands-on experience in applying technology to real-world agricultural challenges, reinforcing the practical value of STEM education. The adoption of project-based and experiential learning approaches made teaching more interactive and student-centered, allowing students to explore problem-solving in agriculture. A notable outcome was the increase in students' interest in STEM, particularly in smart agriculture and ecosystem monitoring, along with improvements in academic performance, teamwork, and problem-solving skills. The interviews also highlighted the program's role in nurturing an entrepreneurial mindset, as students were actively involved in harvesting, packaging, and selling crops, gaining exposure to financial literacy and agribusiness concepts. Additionally, teachers reported that the program strengthened their instructional leadership, enabling them to mentor colleagues in implementing STEM-focused hands-on learning. At the institutional level, the program catalyzed school-wide STEM transformation, leading to new STEM initiatives, leadership support, and interest from students across different grade levels in participating in similar projects. These findings demonstrate that agriculture-based STEM education can effectively enhance student engagement, teacher capacity, and overall school STEM culture

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Table 2: Theme input from teachers reflection

Theme	Teachers' reflection
Integrating Technology in STEM Learning	Gained hands-on experience in IoT-powered fertigation, smart switches, and solenoid-controlled systems. Integrated smart garden monitoring applications in classroom sessions. Use of technology in improving agricultural efficiency.
Project-Based and Experiential Learning	Adopted project-based learning, making teaching more interactive and student-centered. Enabled students to explore and solve real-world agricultural challenges. Enhanced engagement through hands-on applications in fertigation and plant monitoring.
Fostering STEM Interest and Engagement	Students developed greater interest in STEM, particularly in smart agriculture and ecosystem monitoring. Became more proactive and critical in problem-solving. Improved academic performance, teamwork, and confidence in expressing ideas.
STEM-Driven Entrepreneurial Mindset	Students involved in harvesting, packaging, and selling produce. Gained real-world experience in financial literacy and agribusiness. Successfully sold 8.127 kg of chili, generating RM229.00.
Strengthening Instructional Leadership in STEM	Teachers became more confident in leading STEM learning initiatives. Served as mentors for colleagues in hands-on learning. Encouraged inclusivity by providing all students with opportunities in integrated planting.
School-Wide STEM Transformation	More STEM initiatives introduced, such as smart gardens and IoT plant monitoring. School leadership provided

	stronger support for STEM education through resources and training. Other students from different grades expressed interest in joining similar projects.

Conclusion

In conclusion, this case study underscores the potential of agriculture-based STEM education in rural and underserved communities, demonstrating that contextually relevant and hands-on learning experiences can significantly increase student interest in STEM disciplines. The collaborative efforts involving university mentors, trained teachers, and engaged students further emphasize the importance of multistakeholder partnerships in making STEM education more accessible and impactful. Moving forward, scaling the STEMA Garden Module to other rural schools and incorporating longitudinal assessments will be essential to measure the long-term impact on student academic performance and career aspirations in STEM-related fields. Additionally, future adaptations of the module could integrate more advanced agricultural technologies, data-driven precision farming, and entrepreneurial incubation programs to further enhance students' exposure to emerging STEM careers. By continuing to innovate and refine agriculture-based STEM education, programs like STEMA Garden can play a pivotal role in equipping the next generation with the knowledge, skills, and motivation to pursue STEM-related pathways, ultimately contributing to Malaysia's scientific and economic development.

Acknowledgement

We sincerely thank UNESCO for their generous grant (SKUM/STEM/24), which made the implementation of this program possible. We also extend our heartfelt appreciation to the National STEM Association for their trust in our research team to implement the program and ensure the successful achievement of its planned objectives.

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