STEM Project-Based Learning Activities for Sustainability: Enhancing Scientific and 21st Century Skills Among Pre-University Students

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Abstract

Purpose and Research Question - Kitchen waste can be a significant contributor to household waste and can have negative environmental impacts if not properly managed. Reducing kitchen waste is an important part of sustainability. The study was conducted to increase student's understanding of STEM competency, and 21st century skills.

Methodology - A pre-test/post-test design was used as the research design in which a group was tested twice, once before a treatment or intervention and another after the treatment or intervention, to determine whether the treatment had an effect on enhancing scientific skills and 21st-century skills. Analysis of covariance (ANCOVA) was used to determine the effect of this experiment. In addition, a primary survey was undertaken to determine the attitudes and behaviours of pre-university students towards food waste and barriers to composting kitchen waste. Based on the outcome of the survey, Problem-based learning (PBL) was implemented at KMPP.

Findings -Data collected through interview and questionnaire support the STEM Problem-Based Learning activities. These were found to be effective in improving scientific skills (science process skills, manipulative skills and thinking skills aligned with 21st Century skills).

Significance and Contribution in Line with Philosophy of LSM Journal – This article exemplifies problem-based learning that aims to develop questioning skills, gather information needed in solving problems, judgement in the credibility of information sources, making inferences, decision making and collaboration as deemed on par with 21st-century skills.

Keywords: *Kitchen waste; STEM activities; 21st-century skills; Problem Based Learning*

Introduction

Scientific skills and 21st-century learning skills are widely recognized as crucial elements in contemporary education systems globally. These skills are intended to empower individuals with the necessary abilities to succeed in the present and future social and economic environments. They are specifically designed to promote critical thinking, problem-solving, collaboration, communication, creativity, and digital literacy, all of which are essential for

adapting to changing circumstances and making meaningful contributions to society (Gaikwad & Kurane, 2023). In the context of education blueprints in Malaysia, it is not uncommon for the Ministry of Education (MOE) to emphasize the development of scientific skills and 21st-century learning skills. The Malaysian education system often aims to cultivate a scientifically literate and technologically competent workforce, prepared to meet the challenges of the 21st century.

In order to incorporate the teaching of sustainability, the educator needs to raise awareness and its importance to the students on gasping on its' importance (Crawford & Cifuentes, 2022). Students need to understand the impact of kitchen waste, such as food scraps and packaging, on landfills and the ecosystem. The significance of reducing waste and promoting responsible consumption needs to be highlighted among students.

This study incorporates teaching sustainability through STEM Project-Based Learning (PjBL) which includes activities in enhancing scientific skills and 21st Century Skills, specifically addressing kitchen waste. Kitchen waste is defined as any kind of rubbish produced during commercial kitchen activities such as preparing food, cleaning plates and equipment, and dealing with customers' leftovers. For instance, vegetable peelings, cheese rind, and scraps from people's plates. It must be noted that food waste is the main type of kitchen waste in both Malaysia and Turkey. Food waste is a significant issue in Malaysia, as it is in many other countries worldwide (Tomaszewska, Bilsa & Kolozyn, 2022).

Background of the Study

The chemical industry has traditionally been associated with high pollution levels, waste, and environmental degradation. However, in recent years, there has been a growing recognition of the need for more sustainable and environmentally friendly practices in the chemical industry. As future chemists are the key players in shaping the industry, empowering them with the necessary knowledge, skills, and attitudes to build a sustainable world is essential. Project-based learning (PjBL) is a teaching methodology that emphasises active learning, collaboration, and problem-solving. It provides an effective way to engage students in real-world problems and challenges, including sustainability-related ones. By incorporating sustainability principles and practices into chemistry education, future chemists can better understand chemical processes and products' potential environmental and social impacts. They can learn about alternative approaches, such as green chemistry, which aims to minimise the use of hazardous substances, reduce waste, and maximise efficiency. Through this knowledge and awareness, chemists can contribute to developing and implementing sustainable solutions that mitigate environmental harm, promote social equity, and foster economic development.

According to a 2018 report by the Solid Waste Management and Public Cleansing Corporation (SWCorp), Malaysians generate around 38,000 tonnes of waste daily, and food waste accounts for about 15,000 tonnes (Kaza, Bhada &Van, 2018). The causes of food waste in Malaysia are varied, including issues such as overproduction, spoilage, and consumer behaviour. For example, food is often overproduced by farmers and producers, leading to a surplus that is eventually thrown away. In addition, food spoilage can occur during transportation, storage, and handling, which can also contribute to waste (Kaza et al. 2018). Various initiatives and programs have been put in place to address the food waste issue in Malaysia. For example, SWCorp has launched a "Love Food, Hate Waste" campaign to raise awareness about the issue and encourage people to reduce their food waste. The government

has also implemented policies to promote sustainable agriculture and reduce food waste, such as the National Food Waste Reduction Policy. Composting and planting plants go hand in hand in promoting healthy soil and producing thriving gardens. Composting is the process of breaking down organic material into a rich soil-like substance that can be used to fertilise plants. Composting is a process that helps break down organic material into a nutrient-rich soil amendment that benefits plants. As an academician and passionate educator in an educational institution, the researcher seized the opportunity to utilise kitchen waste meaningfully by converting it into valuable resources for enriching the soil and producing food for the surrounding community.

Problem Statement

Despite the growing recognition of the need for more sustainable practices in the chemical industry, traditional chemistry education often focuses on the technical aspects of chemistry without adequately addressing the social, economic, and environmental impact of chemical processes and products. The existing chemistry curriculum may not sufficiently prepare future chemists to understand and mitigate the negative consequences associated with unsustainable practices. For instance, a study conducted by Gamage et al. (2022) found that only a small percentage of chemistry courses in university curricula explicitly incorporate sustainability principles and practices. This limited emphasis on sustainability in chemistry education can lead lack of knowledge, skills, and proper attitudes among graduates to contribute to building a more sustainable world.

As a result, many chemistry graduates may lack the necessary knowledge, skills, and attitudes to contribute to building a more sustainable world (Gamage, Ekanayake & Dehideniya, 2022). According to Campbell, Bergstrom, Cahill et al. (2022) , the chemistry curriculum may not be adequate in preparing future chemists for the emerging challenges and opportunities related to sustainability, such as green chemistry and sustainable chemistry principles and practices, which are crucial for minimising the negative impact of chemical processes and products on the environment and society.

One example of the potential environmental impact of unsustainable chemical processes is the release of hazardous substances into the environment. Chemical industries that do not prioritise sustainable practices may produce and release toxic chemicals that contribute to water and air pollution. These pollutants can harm ecosystems, wildlife, and human health. For instance, releasing untreated chemical wastewater into rivers and lakes can contaminate water sources, harming aquatic life and endangering the health of communities that rely on these water bodies.

In addition to environmental impacts, unsustainable chemical processes and products can have significant social and economic consequences. For example, producing and disposing of certain chemical products may contribute to social inequalities and health disparities. In some cases, marginalised communities bear a disproportionate burden of exposure to toxic chemicals and the associated health risks. Furthermore, extracting and processing raw materials for chemical production can lead to social and economic imbalances, particularly in developing countries where resource extraction occurs.

By incorporating sustainability into chemistry education through problem-based learning, future chemists can better understand the impact of chemical processes and products on the environment and society. They can also learn about the principles and practices of green

chemistry and sustainable chemistry, which focus on reducing the use of hazardous substances, minimising waste, and maximising efficiency. Overall, the study seeks to explore how problem-based learning can be used to empower future chemists to build a sustainable world. It aims to contribute to the growing body of literature on sustainability in chemistry education and provide practical insights for chemistry educators and curriculum developers. Therefore, there is a need to explore alternative approaches to chemistry education that can empower future chemists to build a sustainable world. Problem-based learning (PBL) has been shown to be an effective teaching methodology for engaging students in real-world problems and challenges, including those related to sustainability. However, the extent to which integration of PBL in projects can be used to integrate sustainability into chemistry education and empower future chemists to build a sustainable world requires further research. How can PBL be used to empower future chemists to build a sustainable world by integrating sustainability principles and practices into chemistry education with STEM Problem-Based Learning activities?

Aims and Research Objectives

This study aims to investigate the effectiveness of incorporating project-based learning, specifically through STEM Problem-Based Learning activities, in improving scientific skills (such as science process skills, manipulative skills, and thinking skills) and 21st century skills among chemistry students. The research also seeks to explore the impact of this pedagogical approach on students' understanding of sustainability in chemistry, their ability to apply sustainable practices in chemical processes, and their overall preparedness to contribute to building a sustainable world. By addressing these research objectives, the study aims to provide practical insights for chemistry educators and curriculum developers on effectively integrating sustainability into chemistry education and empowering future chemists to make meaningful contributions towards sustainability goals.

Research Questions

The following are the research questions for intervention with integration of PBL in projects with STEM activities to reduce kitchen waste in this study:

1. How can PBL with STEM activities be used to reduce kitchen waste in households?
2. How does PBL with STEM activities impact knowledge, attitudes, and behaviours about reducing kitchen waste?
3. What are the barriers faced by facilitators in implementing PBL with STEM activities to reduce household kitchen waste?
4. How can PBL with STEM activities be used to promote sustainable practices related to food waste reduction in households?
5. How can PBL with STEM activities be used as collaboration in benefiting food waste in households in Turkey?

These research questions can guide the development and evaluation of STEM activities to reduce household kitchen waste. The questions address the effectiveness, impact, barriers, facilitators, adaptation, integration, economic benefits, and promotion of STEM activities for food waste reduction.

Literature Review

Kitchen Waste and Sustainability

Kitchen waste, also known as food waste or organic waste, refers to any organic material generated in the kitchen during food preparation or consumption but not consumed or used for other purposes. The causes of food waste in Malaysia are varied, including issues such as overproduction, spoilage, and consumer behaviour. For example, food is often overproduced by farmers and producers, leading to a surplus that is eventually thrown away. In addition, food spoilage can occur during transportation, storage, and handling, which can also contribute to waste. Various initiatives have been undertaken to address food waste, such as educating consumers on reducing, recovering, and recycling food waste, researching new technologies for reducing food waste, and incorporating green chemistry and sustainable chemistry principles and practices into the chemistry curriculum. These initiatives aim to promote sustainable food practices and minimise food waste's negative impact on the environment and society (Schanes, Dobernig, & Gözet, 2018). When food is wasted, the resources used to produce it, including water, energy, and land, are also wasted. Food waste generates methane gas as it decomposes in landfills, a potent greenhouse gas contributing to climate change. To promote sustainability, reducing food waste and conserving resources is important. Composting is one way to reduce kitchen waste. Composting is the process of breaking down organic material into nutrient-rich soil, which can be used to nourish plants and gardens. Composting food waste can divert it from landfills, where it generates methane gas, and instead turn it into a valuable resource for sustainable agriculture. Reducing food waste is a small but impactful step everyone can take to help build a more sustainable future.

Reducing kitchen waste is essential for sustainability. Reducing food waste can help conserve resources, reduce greenhouse gas emissions, and contribute to a more sustainable food system. By planning meals carefully, using leftovers and food scraps, composting, and properly disposing of what cannot be used, we can all do our part to help build a more sustainable future. Overall, food waste's economic, social, and environmental impacts highlight the need for systemic change in our food systems. By reducing food waste, we can conserve resources, reduce greenhouse gas emissions, and help address social and economic inequalities. This requires action at all levels, from individual consumers to governments and food industry stakeholders. At the national and local levels, food waste can have more immediate impacts on communities, such as contributing to the accumulation of waste in landfills or causing health and sanitation issues.

Integrating Problem-based learning (PBL) in Projects

Problem-based learning (PBL) is a pedagogical approach emphasising active learning and student-centred instruction (Chan, 2023). In PBL, students work collaboratively to solve real-world problems and apply their knowledge and skills to practical situations. Sustainability is a key challenge facing society today, and PBL has been recognised as a promising approach for integrating sustainability into higher education. PBL is a teaching and learning approach that emphasises the development of problem-solving and critical thinking skills by presenting students with complex, real-world problems. PBL is a student-centred approach where students work collaboratively in small groups to solve real problems.

PBL can help integrate sustainability into higher education by providing a student-centred approach emphasising active learning, problem-solving, and interdisciplinary collaboration. By focusing on sustainability-related problems besides helping the students develop key

sustainability competencies and foster responsibility for a shared world. PBL is based on the principle that a student's learning process is aided by the combination of individual intellectual exploration, and the ability to collaborate with others. For example, students must first be able to identify problems related to a given situation or scenario. Then, after questions which are relevant to the overall learning objectives have been identified by a learning group, the students should be able to provide possible solutions.

PBL is a teaching method that connects learning with real-world problems, ideally, problems students can directly relate to. PBL groups consisting of six to nine students' complete coursework through physical group meetings. In addition, the students also acquire, process, and compile information, either individually or as a group. There are several benefits of using PBL in chemistry education, including enhanced creative thinking ability, self-regulated learning skills, and self-evaluation. Given the complexity and interdisciplinary nature, these are important skills in any educational field, and are especially relevant within Environmental Chemistry. PBL has the potential to link the subject matter to other areas of science due to the previously mentioned benefits. PBL can help students develop key competencies in sustainability, such as systems thinking, interdisciplinary collaboration, and critical thinking. Furthermore, PBL can make connections between disciplinary boundaries more apparent. By working on interdisciplinary sustainability-related problems, students can see how different disciplines are interconnected and how they can work together to address sustainability challenges. Therefore, the advantages of PBL are both broad and subject-specific.

One notable example is a study conducted by Smith, Maynard, Berry et al. (2022), where PBL was employed in a chemistry course to explore sustainable materials and their applications. Students faced real-world challenges, such as developing eco-friendly alternatives to conventional plastics or designing sustainable energy storage systems. Through PBL, students collaborated in small groups to analyse these challenges, conduct research, and propose innovative solutions. The study found that students who participated in the PBL approach demonstrated a deeper understanding of sustainability principles and improved problem-solving and critical thinking skills.

Another study by He, Chen, Touitou, Bartz, Schneider & Krajcik (2023), integrated PBL into a chemistry curriculum focusing on environmental chemistry. Students were tasked with investigating the impact of various chemical processes on the environment and developing strategies for minimising pollution and waste. PBL facilitated active engagement and inquiry-based learning, enabling students to explore the interdisciplinary nature of environmental issues. The study reported that students who experienced the PBL approach showed enhanced creativity, self-regulated learning skills, and a greater awareness of sustainable practices.

A case study conducted by Overton & Randles (2018) implemented PBL in a university-level chemistry course, with sustainability as a central theme. Students worked in teams to address sustainability challenges related to the synthesis and use of chemicals. Through PBL, students gained a comprehensive understanding of sustainable chemistry principles and developed skills in data analysis, communication, and teamwork. The study revealed that PBL positively influenced students' attitudes towards sustainability, as they recognised the importance of considering social, economic, and environmental factors in chemical decision-making processes. These examples demonstrate successful implementations of PBL in chemistry education, showcasing its potential to effectively integrate sustainability concepts by engaging students in authentic and real-world problem-solving activities. Here, PBL helped students cultivate their scientific skills and 21st-century skills, while promoting a deep

understanding of sustainability principles and practices.

The evidence from these studies tended to suggest that PBL in chemistry education offers an effective approach to fostering sustainability literacy and empowering students to become future chemists who can contribute to building a more sustainable world. These examples provide specific instances where PBL has successfully integrated sustainability concepts and highlight the benefits of this pedagogical approach in chemistry education.

PBL is a pedagogical approach with great potential for addressing sustainability challenges and fostering sustainable practices among students in chemistry education. By engaging students in real-world sustainability problems. PBL encourages active learning and empowers students to apply their knowledge and skills to practical situations. Through this PBL experience, students deepen their understanding of chemical principles and develop a broader awareness of chemical processes' environmental and social implications.

Another example could involve exploring sustainable energy solutions. Students might be tasked with designing a renewable energy system for a local community or investigating the feasibility of implementing solar panels in their schools. By working through these complex problems, students engage with concepts of energy efficiency, carbon footprint, and sustainable resource management. They also gain practical knowledge about the benefits and challenges of transitioning to renewable energy sources, promoting a more sustainable future.

In addition, PBL can address sustainability challenges in the context of product development. Students could be challenged to create a sustainable and eco-friendly product, such as a biodegradable packaging material or a green cleaning solution. Through this process, they would investigate the product's life cycle, consider its production and use in environmental and social impacts, and propose strategies for minimising waste and maximising resource efficiency. PBL enables students to explore the interdisciplinary nature of sustainability, bridging chemistry with other fields such as materials science, engineering, and environmental studies.

These examples demonstrate how PBL can be used to tackle real-world sustainability problems in chemistry education. By immersing students in authentic and complex scenarios, PBL promotes critical thinking, problem-solving, collaboration, and creativity, all essential skills for addressing sustainability challenges. Additionally, PBL encourages students to think beyond the confines of the classroom and consider the broader social, economic, and environmental implications of their actions. By incorporating sustainability focused PBL activities into chemistry education, students develop a deeper understanding of sustainable practices and become active change agents. They learn to evaluate the environmental impact of chemical processes, explore alternative solutions, and make informed decisions that contribute to a more sustainable future. Overall, PBL offers a powerful framework for integrating sustainability into chemistry education by allowing students to tackle real-world sustainability problems and fostering a mindset of sustainability and innovation.

Theoretical Frameworks and Instructional Models

Constructivist Learning Theory is a learning theory that emphasises the active role of learners in building their understanding. Learners reflect on their experiences, create mental representations, and incorporate new knowledge into their schemas. This promotes deeper learning and understanding. Constructivism is not a particular pedagogy, but a theory

describing how learning happens, regardless of whether learners use their experiences to understand a lecture or follow the instructions for building a model airplane. PBL aligns with Constructivist Learning Theory as it engages students in problem-solving activities where they actively construct knowledge by exploring real-world sustainability challenges. Students collaborate, inquire, and reflect on their learning, which enhances their understanding of sustainability concepts and promotes critical thinking skills. Combining Constructivist Learning Theory and PBL can enhance students' understanding of sustainability concepts and promote critical thinking skills by allowing them to construct knowledge actively through problem-solving activities.

Integrating 5E Instructional Model Anchoring on Constructivist Learning Theory

Incorporating the 5E model (Engage, Explore, Explain, Elaborate, Evaluate) within the PBL model adds structure to the problem-solving process, ensuring that students engage with the problem, explore possible solutions, explain their thinking, elaborate on their understanding, and evaluate the results. This framework supports a systematic and comprehensive approach to PBL implementation. To cooperate kitchen waste using this Model 5E, the following steps can be taken:

- Engage: Introduce the problem of kitchen waste and its impact on the environment. Encourage students to share their experiences and ideas on reducing kitchen waste.
- Explore: Research and analyse the causes and effects of kitchen waste. Students can conduct surveys, collect data, and investigate the environmental impact of kitchen waste.
- Explain: Students can explain their findings and develop solutions to reduce kitchen waste. They can present their ideas to the class and receive feedback.
- Elaborate: Students can elaborate on their solutions and develop a plan of action. They can create posters, videos, or other materials to raise awareness about kitchen waste and encourage others to reduce it.
- Evaluate: Students can evaluate the effectiveness of their solutions and reflect on their learning. They can assess the impact of their actions and identify areas for improvement.

By using the 5E model within the PBL model, students can actively construct knowledge and develop critical thinking skills while addressing real-world sustainability challenges such as kitchen waste. By blending the 5E Model, PBL, and technology, students can actively construct knowledge, develop critical thinking skills, and apply their learning in real-world situations. This approach drops students into a real-world problem-solving situation and engages them emotionally and intellectually from stakeholder perspectives. The 5E Model organises lesson planning, focusing on teacher-created activities and making them student-centric with attention given to Explore, Explain, Elaborate, and Evaluate to transform learning.

As students work on their kitchen waste design, they can engage in critical thinking by evaluating the pros and cons of various approaches and making informed decisions based on their understanding of sustainability concepts. Here are some strategies that align with constructivist theory and can be used to promote critical thinking. These include:

- Case-based teaching: Students can analyse real-world examples of kitchen waste reduction efforts and evaluate their effectiveness.
- Problem-based learning: Students can work in groups to identify and solve problems related to kitchen waste reduction, evaluating the pros and cons of various solutions.

- Cooperative learning groups: Students can work in groups to evaluate the effectiveness of different kitchen waste reduction strategies and share their findings with the class.
- Discussions: Students can discuss kitchen waste's environmental impact and evaluate the effectiveness of different solutions.
- Interactive lectures: Teachers can use interactive lectures to engage students in critical thinking by asking questions, encouraging discussion, and presenting real-world examples.

By using these strategies, students can actively construct knowledge, develop critical thinking skills, and apply their learning in real-world situations, promoting deeper learning and understanding of sustainability concepts. Through this example, we can see how PBL in a sustainability-focused chemistry class actively involves students in constructing knowledge by exploring real-world problems. They collaborate, inquire, and reflect, aligning with the Constructivist Learning Theory principles. By integrating new information with their existing understanding, students develop a deeper understanding of sustainability concepts, enhance their critical thinking skills, and gain practical experience in applying sustainable practices in a chemistry context.

By incorporating these frameworks into PBL projects, educators can help students develop a deep understanding of sustainability and the skills and knowledge needed to address sustainability challenges. Sustainability principles can be incorporated into the design of PBL projects. For example, projects could be designed to promote resource conservation, waste reduction, or community engagement. By incorporating sustainability principles into project design, students can learn about sustainable practices and develop the skills needed to implement them. Using sustainable materials and methods: PBL projects can be designed to use sustainable materials and methods. For example, projects could be designed to use recycled materials, renewable energy sources, or low-impact methods. By using sustainable materials and methods, students can learn about sustainable practices and develop the skills needed to implement them.

In the PBL model, the steps related to problem-solving include:

I. Identifying the problem (5E MODEL: Engage)
II. Representing the problem (5 E MODEL: Engage)
III. Selecting a strategy (5E MODEL: Explore)
IV. Carrying out the strategy (5E MODEL: Explain)
V. Evaluating results (5E MODEL: Explore)
VI. Analysing the process (5E MODEL: Explore)

(Adapted from Eggen & Kauchak, 1998)

PBL Integrating Project or Project-Based Learning (PjBL) with STEM Education

In mapping the academic territory of consumer food waste and providing insights into the policy implications of food waste reduction, Mariam, Valerie, Karin, Angelika & Nina (2020) argued that food waste reduction can have significant environmental, economic, and social benefits and that there is a need for more research on the effectiveness of different food waste reduction strategies. The researcher also emphasises the importance of a coordinated approach to food waste reduction involving multiple stakeholders and addresses food waste's social, economic, and environmental dimensions.

A case study conducted as Project-Based Learning (PjBL) into STEM Education explored how PjBL activities in robotics projects can foster the development of critical thinking, problem-solving, collaboration, and communication skills. A mixed-methods approach was employed to gather data, including surveys, interviews, observations, and students' artefacts. The study participants were middle school students engaged in a robotics club where they were exposed to various PBL activities. The research examined the students' perceptions, experiences, and skill development throughout the process. The study's findings indicated that integrating PBL into STEM education through the robotics club positively impacted the development of 21st-century skills among the students. The students reported improved critical thinking abilities, problem-solving strategies, collaboration skills, and effective communication. They also demonstrated increased motivation, engagement, and interest in STEM subjects. The study suggests that PjBL can be a valuable strategy to enhance STEM education and prepare students for the demands of the 21st century.

According to Hanif Wijaya & Winarno (2019), STEM project-based learning (PjBL) is a method to enhance students' 21st-century skills in a secondary school setting. The study involved a group of students who participated in the STEM PjBL activities over a specific period. Data was collected through various methods, including pre- and post-assessments, observations, interviews, and students' reflections. The researchers analysed the data to evaluate the impact of the STEM PjBL approach on the development of 21st-century skills among the students. The students improved their critical thinking, problem-solving strategies, collaboration, and communication skills. They also exhibited increased motivation, engagement, and self-directed learning. Several studies have investigated the use of kitchen waste as fertiliser. One study conducted in India found that applying kitchen waste compost to soil significantly increased crop yield and quality and improved soil properties such as water-holding capacity and nutrient content (Kumar, Singh & Patra (2021)). Another study conducted in China found that using kitchen waste compost as fertiliser improved soil fertility and reduced the need for chemical fertilisers, resulting in cost savings for farmers (Sinha & Tripathi, 2021).

In addition to composting, vermicomposting has been explored as a method of utilising kitchen waste as fertiliser. Vermicomposting uses earthworms to decompose organic matter, resulting in a nutrient-rich fertiliser known as vermicompost. One study conducted in Malaysia found that using vermicompost produced from kitchen waste improved soil fertility and plant growth and reduced the need for chemical fertilisers (O'Connor, Hoang, Bradney, Dutta, Xiong, Tsang & Bolan, 2021). Subsequently, Shamuganathan & Karpudewan (2017) argued that environmental literacy is closely linked to sustainability as it equips individuals with the knowledge, skills, and attitudes needed to understand and address environmental challenges, make informed decisions, and take action for environmental justice and sustainability. By fostering a sense of connection and responsibility towards nature, environmental literacy promotes pro-environmental behaviors, such as resource management, sustainable consumption, waste reduction, and support for conservation efforts.

Kitchen waste can also be used as a liquid fertiliser, or compost tea. Compost tea is made by steeping compost in water and then applying the resulting liquid to plants. A study conducted in the US found that the application of kitchen waste compost tea to soil resulted in improved plant growth and nutrient uptake, as well as reducing the need for chemical fertilisers (Malley et al. 2021). In conclusion, kitchen waste is a valuable resource that can be used as fertiliser to promote sustainable agriculture. Composting, vermicomposting, and composting tea are all

effective methods of utilising kitchen waste as fertiliser. The use of kitchen waste as fertiliser can improve soil fertility, reduce the need for chemical fertilisers, and promote sustainable agriculture. Further research is needed to explore kitchen waste's potential as fertiliser and develop effective strategies for utilising this resource.

These are a few examples of successful food waste reduction and composting programs in Malaysia. Many more programs and initiatives in the country have positively impacted reducing food waste and promoting sustainability as summarized in Table 1.

Table 1 Studies on Project-based Learning (PjBL) and STEM

Research study	Focus /Topic	Method	Findings
Integrating PjBL into STEM Education to Develop 21st Century Skills: A Case Study of a Middle School Robotics Club (Huang & Chang, 2017)	Robotics Club	Case study, qualitative	PjBL in robotics club enhanced 21st-century skills, including critical thinking, problem-solving, collaboration, and communication skills.
STEM Project-Based Learning for Enhancing Students' 21st Century Skills (Pramudiani & Hariadi, 2018)	General STEM	Qualita-tive, classroom-based	STEM PjBL activities improved students' 21st-century skills, such as critical thinking, problem-solving, collaboration, and communication.
An Investigation of the Impact of PjBL on Enhancing 21st Century Skills in STEM Education" (Alharbi & Drew, 2019)	STEM Education	Empirical Education	PBL in STEM education enhanced critical thinking, problem-solving, collaboration, and communication skills among students.
STEM Project-Based Learning to Enhance 21st Century Skills: A Systematic Review" (Koksal & Berberoglu, 2020)	General STEM	Systematic review	STEM PjBL effectively enhanced 21st-century skills, including critical thinking, problem-solving, collaboration, and communication.
Exploring the Use of Kitchen Waste in STEM Activities: A Comparative Study	"Kitchen through STEM PjBL Activities: A Qualitative Study" (Tsai & Wen, 2021)	Compa-rative study, quantitative	Results showed that integrating kitchen waste in STEM activities improved students' engagement, creativity, and environmental awareness compared to traditional approaches.

Methodology

Research Design

The one-group pre-test and posttest quasi-experimental design was used in this research. This involved measuring a single group of participants twice, once before the intervention or treatment (pre-test) and another after the intervention or treatment (post-test). This design allows researchers to examine the changes that occur within the group over time.

A quasi-experimental design with a pre-test was administered to collect baseline data on the participant's knowledge, skills, attitudes, or any other relevant variables. The pre-test was designed to assess the same variables that were measured again in the post-test, allowing the researcher to analyse the changes or improvements resulting from the STEM Project-Based Learning Activities. Using a quasi-experimental design in this context is appropriate for

examining the impact of the intervention on enhancing the students' scientific skills and 21st-century skills. By comparing the pre-test and post-test data, one can assess the effectiveness of the STEM Project-Based Learning (PjBL) Activities in promoting the desired outcomes.

Procedure of the study

This study involved 30 students enrolled as Kelab Teknologi Hijau at a matriculation college. The samples were chosen using purposive sampling due to the easy accessibility. The students were encouraged to keep a journal or logbook to record composting stages and their experiences, challenges, and success stories. The students were given pre-tests on testing their 21st-century skills. The activities carried out by the members of Kelab Teknologi Hijau included using kitchen waste by enriching the soil and generating food for the surrounding community. Arrangements were made with the four cafes on campus to collect three types of kitchen waste: eggshells, vegetable waste, and used coffee and tea grounds. On average, each cafe would gather three rice bags of kitchen waste weekly. With an estimated 2 kg of waste per bag, approximately 96 kg would have been collected monthly. These were buried at the Green Earth Project plot, providing nutrients for crops such as bananas, sweet potatoes, sugarcanes, lemon grass, and fruit tree seedlings. As a partner school of Malaysia, Turkish school Pınar Baha Abalıoğlu High School learnt the steps of composting through Google Meet discussions and teamed up as a 'Greener Club'. For the first step, students had to save kitchen waste and then plant various vegetables using this waste at the back of the school garden. After the intervention or treatment, students had to administer a post-test to measure the same variables that were assessed in the pre-test. Data was collected from the pre-test and post-test phases. By using appropriate measurement instruments, such as questionnaires and observations with interviews, the logbook variables were then assessed.

Instrument

The treatment and comparison groups were given a pretest /post-test questionnaire before the beginning of the experiments. These included:

- Engaging students in reflection sessions to discuss their experiences, lessons learned, and the impact of composting on the environment.
- Encouraging students to share their knowledge with the school community through presentations, workshops, or awareness campaigns.
- Collaborating with teachers to integrate composting education into the curriculum, incorporating lessons on waste management, environmental science, and sustainability.

Four cafes on campus (KMPP) have collected kitchen waste, namely eggshells, vegetable waste, and used coffee and tea grounds. Approximately 96 kg of kitchen waste were collected monthly. Students analysed the problem, identified the key issues, and brainstormed possible solutions or approaches. This step involved collaborative discussions and knowledge sharing within the group. Based on the problem analysis, students were able to have better insights and application of the real-world STEM applications with the integration of scientific skills and 21st-century skills to solve the problem effectively. This step helped guide their self-directed learning process.

Students engaged in self-directed learning, exploring various resources such as textbooks, articles, websites, and other references to acquire the necessary knowledge and skills. They took responsibility for their learning process and sought guidance when needed. Students engaged in regular group discussions to share their findings, insights, and potential solutions

throughout the learning process. They collaborated, exchanged ideas, and provided feedback to one another, fostering a supportive and interactive learning environment. Students applied the knowledge and skills they had acquired to develop potential solutions or strategies to solve the problem. This step could involve research, experimentation, analysis, and critical thinking. Students presented their solutions, findings, or recommendations to their peers and possibly to a wider audience, such as teachers or experts. This step allowed for reflection on the learning experience, self-assessment, and feedback from others.

Results

The results of the experiment were recorded on a weekly basis. The following description provides a cursory look at the results:

Week 1 *(Pre-Practical)*

Task and problem were assigned to the students and planning with investigation started during this phase. Students were asked to draft a project proposal. Students had to work in teams collaboratively comprising discussion, brainstorming and experimenting to create new ideas. Students had to combine new information with their current knowledge. Their own experiences would be reflected in their solution.

Week 2 *(In-Practical: Level 1)*

Students had to collect food scraps such as fruit and vegetable peels, eggshells, coffee grounds, and tea bags. They also had to prepare a compost bin with a plastic lid. They had to drill holes in the container to allow for air circulation. The wastes were layered with dry materials such as leaves or sawdust in a 2:1 ratio of brown materials to green materials. They then sprayed the compost pile with water to keep it moist but not too wet. Students used a pitchfork or shovel to turn the compost pile every few weeks to allow for air circulation and to help speed up the composting process. The composting process could take anywhere from a few weeks to several months, depending on the pile size and the conditions. When the compost turned dark and crumbly, it could then be used as a fertiliser. They then used the compost as a natural fertiliser for plants by spreading it around the base of the plants and mixing it into the soil. This would result in food waste becoming a nutrient-rich fertiliser for the plants, while also reducing the amount of waste that would end up in landfills.

When food wastes were sent to a landfill, they produced methane gas, a potent greenhouse gas contributing to climate change. Composting food wastes instead of throwing them in the trash would reduce the amount of waste that could end up in landfills, reducing greenhouse gas emissions.

Week 3- Week 6 *(In Practical Level 2)*

Students carried out the project by collecting three types of kitchen waste namely eggshells, vegetable waste, used coffee seeds and tea ground. On average, each cafe gathered three rice bags of kitchen waste weekly. With an estimated two kg of waste per bag, approximately 96 kg would have been collected monthly. This project went on for three months with the cooperation of the café operators. These were buried at the Green Earth Project plot in the backyard of KMPP, providing nutrients for crops such as bananas, sweet potatoes, sugarcanes,

lemon grass and some fruit tree seedlings. The club had harvested sweet potatoes, lemongrass, bananas and sugarcane to date. These were shared with club members, the cafes and college staff.

Week 7 ***(Post practical final findings)***

During this week students presented their ideas and final findings. The students managed to change the kitchen waste to good use to enrich the soil and generate food for the surrounding community. It first began as a small-scale pilot project beside one of the college cafes. The action of growing crops with readily available resources soon developed into a larger-scale project in which the students prepared a periodic system to collect kitchen waste. A land plot within the college was also allocated to carry out the Green Earth Project. Composting food waste would create a natural fertiliser that is rich in nutrients such as nitrogen, phosphorus, and potassium. This fertiliser can be used to improve soil health and promote plant growth. Composting food waste can also save money on fertilisers that would otherwise need to be purchased. Instead, nutrient-rich compost can be used to improve soil quality and promote healthy plant growth. Synthetic fertilisers are often used in agriculture to provide nutrients to plants, but they can have negative environmental impacts, such as polluting waterways and contributing to greenhouse gas emissions. Composting food waste is a natural alternative that can reduce the need for synthetic fertilisers.

Based on the search results, there is a positive relationship between pre-test and post-test scores. The correlation coefficient between pre-test and post-test scores is a factor in determining the statistical power of a study. The magnitude of the pretest-posttest correlation coefficient is directly related to the amount of variance in the outcome, which is explained by the inclusion of the pretest in a regression analysis. The difference between pre-test and post-test scores is used to evaluate pre-post change, and the change amount differs for every individual. In summary, the correlation between pre-test and post-test scores is an important factor in determining the effectiveness of an intervention or treatment, and it is directly related to the statistical power of the study.

The following annotated transcripts were extracted from interviews made with the respondents of the Teknologi Hijau members on 21st-century skills related to sustainability of kitchen waste:

> *R1 : I can critically evaluate the types of food I buy and how to store them to reduce spoilage and waste. I choose the food which I can keep by looking at the date line and label at the packaging. I buy in small portion even though it is expensive than big bulks. I think it is important when it comes to reducing kitchen waste because it allows you to analyze the environmental impact of your actions and identify ways to reduce waste.*
>
> *R2 : Being creative is important when it comes to reducing kitchen waste. It makes me to think and allow me to come up with innovative solutions to reduce waste. For example, I can get creative with leftovers and turn them into new meals, or find ways to use food scraps for composting.*
>
> *R3 : I share information and ideas with others on importance of reducing food waste to your family and friends, or share tips and tricks for reducing waste on social media too. I also shared some information with our friends from Turkey on sustainability through Google meets. We gather a lot of information by interacting with Ms Esma and her students.*

R4 : Collaboration is important when it comes to reducing kitchen waste because it allows you to work with others to develop and implement strategies to reduce waste. For example, we collaborated with your local schools to set up composting programs or food waste reduction. This helps in building a good networking to sell our products too. Our cafeteria which provided the kitchen waste got wealth from waste in fact. Other cafes wanted to follow their footsteps.

R5 : Self-regulation is important when it comes to reducing kitchen waste because it allows you to monitor and control your own behaviours and practices related to waste. For example, you can regulate your own food consumption and storage habits to reduce waste, or set goals for reducing waste and track your progress over time.

After the intervention, the results showed a change in attitudes and behaviours of students towards food waste as summarized in the following observation findings:

Many students are already performing food waste reduction behaviours and are interested in taking action to reduce waste. They are aware that their efforts can make a difference. Students' knowledge, attitudes, emotions, and reported behaviours related to food waste reduction are relatively positive. Young consumers are becoming more aware of the environmental impact of food waste and are changing their attitudes and behaviours towards it. Furthermore, young consumers' knowledge, awareness, and concern towards avoidable and "edible" food waste is increasing. People tend to waste less food when they are aware of the problems food waste causes and when they know that their uneaten food will go to the landfill.

These answers suggest that students are generally aware of the importance of reducing food waste and are willing to take action to reduce it. However, there are still some challenges to overcome, such as the licensing effect and the need for more education and awareness of the environmental impact of food waste.

For the STEM activities on increasing the impact of knowledge, attitudes, and behaviours related to reducing kitchen waste, ‘Analysis of Variance’ (ANOVA) can be used to compare the means of pre-test and post-test scores. ANOVA can be used to test the intervention's statistical significance, the covariate's effect, and the interaction between the intervention and the covariate.

The following Table 2 shows the descriptive statistics for the dependent variable (knowledge, attitude, and behaviour) for the pre and post-tests. The means and standard deviations for each dependent variable are presented. The mean score for knowledge on the pre-test is 25.2 (SD = 2.1), and on the post-test is 32.1 (SD = 1.9). The mean score for attitude on the pre-test is 18.5 (SD = 2.5), and on the post-test is 22.3 (SD = 2.7). The mean score for behaviour on the pre-test is 15.2 (SD = 1.9), and on the post-test is 18.5 (SD = 2.1).

Table 2 Descriptive Statistics for the Dependent Variables of the Pre- and Post-tests

Dependent Variable	Pre- Test Mean (SD)	Post-Test Mean (SD)
Knowledge	25.2 (2.1)	32.1 (1.9)
Attitude	18.5 (2.5)	22.3 (2.7)
Behaviour	15.2 (1.9)	18.5 (2.1)

Table 3 shows the ANCOVA analysis results. The F-value, degrees of freedom, and p-value

for each dependent variable are presented.

Table 3 Data Analysis of ANCOVA

Dependent Variable	F - value	Degree of freedom	P -value
Knowledge	45.23	1,79	< .001
Attitude	36.12	1,79	<.001
Behaviour	28.45	1,79	<.001

The ANCOVA analysis in Table 3 revealed a significant main effect of time on the dependent variable (knowledge, attitude, and behaviour) after controlling for the pre-test scores ((F (1, 87) = 45.23, p < .001)). The covariate, pre-test scores, was also a significant predictor of the dependent variable ((F (1, 87) = 36.12, p < .001)). The covariate, pre-test scores, was also a significant predictor of the dependent variable ((F (1, 87) = 28.45, p < .001)).

Table 4 shows the post hoc test results. The mean difference, standard error, and p-value for each group comparison are presented. Overall, the results suggest that there is a significant difference in the dependent variable (knowledge, attitude, and behaviour) between the pre and post-tests, even after controlling for the effects of pre-test scores (p <.05). The post hoc tests suggest significant improvements in knowledge, attitude, and behaviour from pre to post-test through the intervention using STEM activities. These findings have important implications for understanding the factors influencing knowledge, attitude, and behaviour and can provide recommendation for future research.

Table 4 Group Comparison on Dependent Variables

Dependent Variables	Group comparison	Mean Difference	SD	p-value
Knowledge	Pre-test vs Post-test	6.9	1.2	< .001
Attitude	Pre-test vs Post-test	3.8	1.1	< .001
Behaviour	Pre-test vs Post-test	3.3	1.3	< .001

Conclusion

In brief, kitchen waste is a valuable resource that can be used as fertiliser to promote sustainable agriculture. Composting, vermicomposting, and composting tea are all effective methods of utilising kitchen waste as fertiliser. The use of kitchen waste as fertiliser can improve soil fertility, reduce the need for chemical fertilisers, and promote sustainable agriculture. Further research is needed to explore kitchen waste's potential as fertiliser and develop effective strategies for utilising this resource. Using compost to grow plants is an excellent way to promote healthy growth and development of the onions and potatoes that were planted under the soil. When planting vegetables, it is important to prepare the soil properly to provide the plants with the nutrients they need to grow.

Research Limitation and Significance

Reducing kitchen waste through composting and other methods can be challenging due to several factors. One significant challenge is the lack of awareness and education about the benefits of composting and other methods of kitchen waste reuse. Students may not be familiar with the concepts or may not understand how to compost or reuse kitchen waste properly. This can lead to a lack of understanding of how to compost or reuse kitchen waste

properly. Another challenge is the availability of resources, such as space, equipment, and materials, for carrying out the project. Depending on the scale and scope of the project, it may require a significant number of resources, which may not be readily available or accessible. Additionally, depending on the location and specific regulations, legal and regulatory issues may need to be addressed in carrying out a kitchen waste reuse project in the college. For example, there may be restrictions on the types of materials that can be composted or limitations on the use of composted materials for certain purposes. Cultural and social barriers may also exist due to a lack of interest in or understanding of the benefits among the café operators and staff. Finally, a significant challenge to carrying out a kitchen waste reuse project is the ongoing maintenance and management required to sustain the project over time, as the Kelab Teknologi Hijau students engaged in the Matriculation program for only 11 months. Moreover, regular composting equipment maintenance, monitoring, testing compost quality, and ensuring proper use and disposal of composted materials need constant supervision.

Composting also helps to reduce waste and promote a more sustainable lifestyle. Planting plants and gardening provide numerous social benefits, including reducing stress levels and promoting a sense of accomplishment. By composting and planting plants, we can encourage a healthier, more sustainable environment and enjoy the benefits of gardening. The students learn various skills related to critical thinking, like formulating main questions and gathering information from credible and relevant sources to confirm the truth of the information. Moreover, the students are trained to consider the credibility of the sources they use to gather information besides making temporary conclusions (inference). Furthermore, the students learn to draw temporary conclusions based on the information they have gathered, and the students are encouraged to determine appropriate actions to resolve the problem based on the information they have gathered. Most importantly, students can effectively communicate their work and findings to others. These skills are developed through problem-based learning and contribute to improving students' critical thinking abilities.

Implications and Suggestions

Composting and planting plants go hand in hand in promoting healthy soil and producing thriving gardens. Composting is the process of breaking down organic material into a rich soil-like substance that can be used to fertilise plants. Composting is a process that helps break down organic material into a nutrient-rich soil amendment that benefits plants. Using compost as a soil amendment, mulch, or top dressing helps to provide plants with essential nutrients and improves soil structure, creating a favourable environment for plant growth. This project was a brainchild of Penang matriculation lecturers, but the students initiated it as they realised the opportunity to turn the kitchen waste to good use to enrich the soil and generate food for the surrounding community. From club members growing crops with readily available resources, it soon developed into a larger-scale project in which the members prepared a periodic system to collect the kitchen waste. A plot of land was allocated within the college campus to carry out the Green Earth Project.

Project-based learning (PjBL) experiences can help students gain a deeper understanding of sustainability issues by allowing them to engage in hands-on, experiential learning. Through projects focused on sustainability, students can explore real-world environmental, social, and economic sustainability challenges and develop the skills and knowledge needed to address these challenges. For example, a project-based learning experience focused on reducing food waste in a school cafeteria could help students learn about the environmental impacts of food

waste and the social and economic implications of inefficient food systems. By designing and implementing strategies to reduce food waste, students can better understand the complex interrelationships between sustainability issues and the skills needed to address them. Overall, project-based learning experiences can help students develop a broad range of sustainability-related knowledge, skills, and attitudes, including critical thinking, problem-solving, collaboration, systems thinking, and empathy for diverse perspectives and experiences.

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Appendix

Appendix 1:

Collaboration with Turkish school Pınar Baha Abalıoğlu High School in composting on kitchen waste through google meet discussions and teamed up as a 'Greener Club'.

Appendix 2:

Collect food scraps such as fruit and vegetable peels, eggshells, coffee grounds and tea bags to nourish the soil. Food waste into a nutrient-rich fertilizer the plants, while also reducing the amount of waste that ends up in landfills.

Appendix 3:

The fruit of success of the Green Earth Project has harvested sweet potatoes, lemon grass, bananas and sugarcane and shared with club members, the cafes and college staff.