THE IMPLEMENTATION OF INTERDISCIPLINARY STEM PROJECT-BASED LEARNING (PJBL) IN MALAYSIAN PRIMARY SCHOOL

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Abstract: This study investigated how teachers implement interdisciplinary STEM Project-Based Learning (PjBL) in Malaysian primary schools and identified associated challenges. A qualitative case study was employed, collecting data from teacher interviews, curriculum documents, and thematic analysis. Findings indicate that projects align with national curriculum standards, integrate real-world themes, and foster collaboration, critical thinking, and creativity. Nonetheless, teachers struggle with selecting suitable themes, addressing varied student abilities, and managing insufficient PjBL expertise. Constrained resources, limited training, and minimal classroom time further impede successful implementation. Despite these barriers, teachers acknowledge PjBL's potential to enhance 21st-century skills. The results suggest that robust professional development, curriculum flexibility, and supportive policies can strengthen PjBL integration. Future research should expand the sample scope and track longitudinal outcomes to gauge how sustained interdisciplinary STEM PjBL exposure influences students' learning and career aspirations. Overall, well-implemented PjBL supports Malaysia's educational goals and advances sustainability awareness among learners.

Keywords: Interdisciplinary, Project-Based Learning (PjBL), Science, Technology, Engineering, and Mathematics (STEM).

Introduction

STEM teaching integrates Science, Technology, Engineering, and Mathematics through hands-on, inquiry-based strategies emphasising real-world applications (Stohlmann *et al*., 2012; Han *et al*., 2015). This approach fosters critical thinking, creativity, collaboration, and problem-solving skills. Effective implementation involves careful planning, alignment with objectives, and interdisciplinary projects that connect STEM concepts to real-life contexts, enhancing engagement and learning outcomes (Moore *et al.*, 2014; Siew *et al*., 2015). Among various strategies, Project-Based Learning (PjBL) is particularly effective in promoting active learning and critical thinking by involving students in solving real-world problems (Haatainen & Aksela, 2021; Martinez, 2022).

The Ministry of Education (MoE) proposed an integrated STEM teaching framework to develop students' interdisciplinary knowledge, skills, and values (MoE, 2016). This framework emphasises project-based and inquiry-based learning as effective methods for contextualising science and mathematics while fostering STEM-related behaviours (Figure 1).

It provides a structured approach for teachers to implement STEM education aligned with Malaysia's educational goals. The framework also shows teaching with a STEM approach that is contextualised in the real world, referring to daily life, nature, and local and global society (MoE, 2016).

In the context of Malaysia, STEM education was first introduced to students at various levels, starting from primary school, as shown in Figure 2. STEM education in primary schools aims to build students' knowledge, skills, and values, fostering meaningful connections through learning experiences while enhancing their enthusiasm for science (Tomková, 2024).
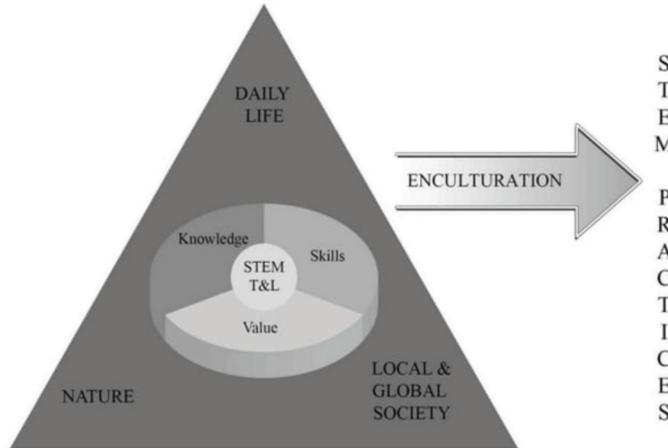
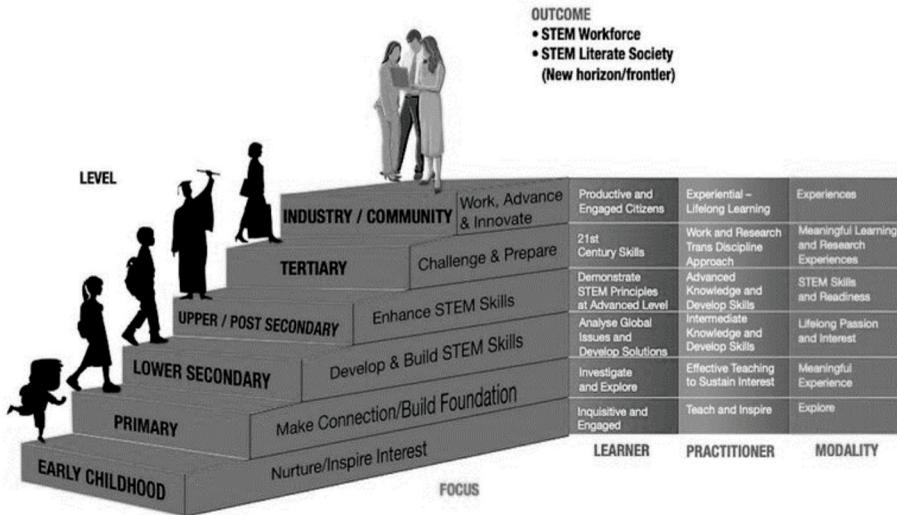Figure 1: Framework for STEM teaching practices

Figure 2: STEM education conceptual framework
Source: Malaysia Education Blueprint (2013-2025)

With the implementation policy and framework provided by the MoE, teachers are required to apply these strategies in schools, starting from the primary level. This initiative aligns with efforts to foster students' interest and competency in STEM subjects from an early age, ensuring foundational knowledge and skills are developed for future challenges (MoE, 2016).

The implementation of STEM PjBL in Malaysian primary schools faces several challenges that must be addressed for effective integration. One major obstacle is the lack of resources such as appropriate materials, tools, and facilities to support interdisciplinary project-based activities (Margot & Kettler, 2019). Additionally, inadequate teacher training in STEM PjBL pedagogy limits their ability to implement this approach effectively (Shernoff *et al.*, 2017). Teachers also struggle to align project themes with existing curriculum standards, creating challenges in ensuring continuity between learning content and project activities (Nadelson *et al.*, 2013). Time constraints further complicate the process, as

planning and executing STEM projects require significant time, which can disrupt annual teaching plans (Ravitz *et al*., 2012). Therefore, exploring how teachers implement integrated STEM PjBL in primary schools is crucial to identifying effective strategies for overcoming these challenges. Such research can provide valuable insights into teachers' practices, support needed improvements in training and resources, and ensure more effective and holistic implementation of STEM PjBL, aligning with the goals of the Malaysia Education Blueprint 2013 to 2025 (MoE, 2016).

The research aims to explore how teachers apply PjBL in Teaching and Learning (T&L) at the primary level and investigate the challenges they face in implementing interdisciplinary STEM PjBL. These objectives provide valuable insight into improving STEM instruction and addressing barriers to its effective integration in primary schools. This study aims to:

(i)   Explore T&L practices of primary school teachers in interdisciplinary STEM PjBL.

(ii) Investigate the challenges teachers face during its implementation.

Through this evaluation, the study seeks to provide insights into improving STEM education practices in Malaysian primary schools.

Research Methodology

A case study design was adopted in this research to facilitate an understanding of the process of implementing interdisciplinary STEM Project-Based Learning (PjBL) in primary school lessons. A qualitative approach was employed, involving document reviews and interviews to gain a deeper, more comprehensive understanding of STEM PjBL across diverse school contexts (Yin, 2014). The participants, Science teachers planned and conducted T&L sessions and served as the focus group for this study. The instruments used were interview protocols and checklist forms. The semi-structured interview protocol contained 10 questions, focusing on the detailed implementation of STEM Project-Based Learning (PjBL), teachers'

perspectives on its execution, and the challenges faced. While the checklist form included items on project planning information, T&L documentation, student feedback on STEM PjBL implementation.

Four schools were selected using purposive sampling, involving eight Science teachers. The main criteria for school selection are schools involved in the pilot programme for STEM model schools under the STEM initiative by the MoE, which have been briefed on the implementation of interdisciplinary STEM Project-Based Learning (PjBL). Additionally, the researcher selected schools of different types and sizes to gain comprehensive insights into the implementation. The interviews were thematically analysed to address the research questions and data were triangulated using document review data. The findings will provide insights into the implementation of interdisciplinary STEM PjBL at the primary level and the challenges faced by teachers.

Results and Discussion

The interviews and document reviews were analysed to examine how teachers implemented interdisciplinary STEM PjBL during two semesters in 2022. The study involved eight respondents from four schools across different states in Malaysia. Schools varied by size (small: < 500 students, large: > 500 students) and location (urban/rural). Teachers had four to 20 years of science teaching experience, with varying levels of interdisciplinary STEM PjBL training, ranging from no training to sessions at school, district, state, or national levels. Table 1 provides the demographic characteristic of respondents of the study.

RQ1: How Teachers Implementing Interdisciplinary STEM Project-Based Learning in Primary School Lesson?

Based on the three data sources collected in two phases, namely the planning and implementation phases, six main themes were identified as the key elements in the implementation of integrated STEM Project-Based Learning (PjBL). These

Table 1: Demographic characteristic of respondents of the study

Respondent Code	School Code	State	Types of School	Categories of School Refer to Number of Students	Experience in Teaching Science	Received Training to Implement Interdisciplinary STEM PjBL
T1	S1	Selangor	Urban	Large (student > 500)	6 years	Once from MoE level, once from school level. Total: 2
T2	S1	Selangor	Urban	Large (student > 500)	15 years	Once from school level. Total: 1
T3	S2	Kedah	Rural	Small (student < 500)	10 years	Once from school level, once from state level. Total: 2
T4	S2	Kedah	Rural	Small (student < 500)	7 years	Once from MoE level, once from school level. Total: 2
T5	S3	Johor	Rural	Large (student > 500)	20 years	Never Total: 0
T6	S3	Johor	Rural	Large (student > 500)	4 years	Once from MoE level, once from school level. Total: 2
T7	S4	Terengganu	Urban	Small (student < 500)	7 years	Once from district level, once from school level. Total: 2
T8	S4	Terengganu	Urban	Small (student < 500)	13 years	Once from school level. Total: 1

themes provide a key element for understanding the critical components necessary for execution of interdisciplinary STEM PjBL.

Based on National Curriculum

During the planning of STEM projects, teachers agree that they could utilise the national science syllabus by referring to the appropriate content and learning standards related to knowledge and skills, applying them to problem-solving within the project. For example, notes from the Year 5 master lesson plan at S1 indicate that the chosen project tittle was "Fruit Plucker". Table 2 presents the learning standards from all subjects involved in the "Fruit Plucker" project.

The interdisciplinary approach in the Year 5 "Fruit Plucker" project integrates learning standards from Science, Mathematics, Malay Language, and Visual Arts. In Science, students design a simple machine-based device, applying knowledge of everyday tool use. In Mathematics, they measure length accurately while constructing the fruit picker. For Malay Language, students develop storytelling skills to recount the fruit season with correct pronunciation and intonation. Lastly, Visual Arts involves creating a product that demonstrates creativity and building skills. These knowledge and skills are combined to produce a complete, integrated project.

Teachers employ a method of deconstructing and reassembling curriculum standards to plan projects. The selections of themes were found related to daily life context, environmental, and community's issues (MoE, 2016). From interview sessions, teachers said that:

> "We plan the project based on learning standard and performance standard. We are encouraged to plan as early as the beginning of the year for each project" - [T01]

> "We need to identify appropriate learning standards for STEM projects, especially those that can be linked to real-world context themes"- [T03]

This supports that the project planning process is align with the implementation of the national curriculum. Teachers will apply knowledge, skills, and values in each topic studied to solve authentic problems through projects.

PjBL STEM requires purposeful design to align with curriculum standards. Many teachers assume that PjBL requires a greater variety of understanding. As a result, many are hesitant to utilise PBL as their preferred pedagogy since they believe it is incapable of covering as much material as a traditional lecture-based approach (Darling-Hammond *et al.*, 2020). In PjBL STEM, curriculum covering is implemented

Table 2: Learning standards from all subjects involved in the "Fruit Plucker" project

Project Title	Year	Learning Standard Based on Subject Involved			
		Science	Mathematics	Malay Language	Visual Arts
Fruit Plucker – in fruit season	5	10.1 Usage of tools in daily life (10.1.1 – 10.1.5) (Create a device utilising at least one type of simple machine)	5.1 Measurement of length (5.1.1 – 5.1.5) (Apply length measurement skills in producing a fruit picker using correct and precise units)	1.3 Tell and recount what has been heard, read, or watched with correct pronunciation and intonation (1.3.1 – 1.3.2) (Story-telling about mango fruit season)	3.1 Creation of creative work (3.1.3) (Produce a work or product development)

horizontally by applying knowledge and skills in current syllabi year or vertically by existing knowledge or beyond.

Problem Oriented Project-Based Learning

Project-Based Learning is significant because it is applicable to real-life situations and aims to solve problems that are relevant to students. This learning can help kids develop a sense of environmental responsibility. According to John Dewey in the 21st Century (Williams, 2017), engaging pupils in meaningful projects can increase their personal investment and improve their creativity and critical thinking skills. This occurs when students encounter challenges during learning. This allows students to improve their mental processes based on their individual needs. From interview sessions, teachers said that:

> *"We always started our project with giving issues to students, to trigger their attention and empathy. The issues were relevant to them, like something they familiar with. The class become happening because they can actually discuss about it" - [T04]*

> *"The project starts with a problem; the teacher needs to develop students'*

thinking by asking various questions"
- [T05]

Data shows that STEM projects implemented by teachers are problem-oriented. Pupils will associate the problem with the knowledge and skills they have learned or existing knowledge to solve the problem critically and creatively. Complex and ill structured problems cannot be solved with one discipline and instead require the combination and integration of knowledge and skills from various disciplines or referred as interdisciplinary (Wulandari *et al.*, 2023).

The researcher gathered several examples from the instructional resources illustrating how teachers initiate a project by providing a problem or issue that encourages students' problem-solving abilities, beginning with the step of empathy. This method corresponds with the design thinking framework and fosters critical and creative thinking abilities. Table 3 presents examples of issues or scenarios that form the basis for initiating a project in STEM PjBL.

These project notes clearly show that each project begins with a problem to stimulate students' thinking and problem-solving skills. Meanwhile, the PjBL steps guide students to systematically produce a problem-solving

Table 3: Examples of issues or scenarios that form the basis for initiating and subject involved in STEM PjBL executed by teachers in 2022

Project Title	Year	Scenario/Problems	Subject Involved	Project Summary
Healthy Plate	3	Children need sufficient nutrition to grow up healthily. One of the meals we eat is breakfast. Can you name the breakfast you usually have? Is it healthy? Let's prepare a healthy breakfast that is well-balanced, nutritious, and delicious.	Science: Food Pyramid Physical & Health Education: Topic Healthy and Safe Eating Practices English: Topic Speaking Skills	This project aims to help students understand the concept of a nutritious meal, focusing specifically on breakfast. It begins with the Science subject under the topic "Food Pyramid", where students learn about nutritional content. Meanwhile, in Health Education, they are introduced to healthy eating habits. Students are then assigned the task of planning a set of meals according to nutritional needs and preparing those meals during the next Science class. In English class, students create a food pyramid model and write a presentation text about their meal. The project spans two weeks in total.

From Trash to Cash	5	A stimulus video shows that the world is filled with various types of waste—one day, we might even be buried under trash! How can we solve this? One solution is the 3R approach. All students are encouraged to bring items they plan to throw away but can still be reused or repurposed into valuable products. Let's turn "trash to cash" while helping to save our planet.	Science: Topic Waste Management Mathematics: Topic Problem Solving of Measurements Visual Arts: Topic Product Creation	This project raises students' awareness of the need to control increasing waste. They explore household waste that can be repurposed into useful items. Applying their knowledge of Waste Management from the Science subject, students empathise with the problem and plan to create products using waste materials they collect at home. The project is integrated with Visual Arts for product creation and Mathematics measurement skills are applied during the production process. The entire project spans three weeks.
My Pet Home	6	Pets need a comfortable place to live, even when they share a home with people. Rara wants to get a pet and make sure it can live comfortably, complete with food and water bowls, along with anything else it needs for a cozy life at home. Can you help Rara? Choose a pet and build a house for it.	Science: Topic Stability and Strength Materials RBT: Product Creation English: Language Arts	This project begins with students understanding the concepts of stability and material strength to create products with specific functions. The teacher provides a problem scenario, prompting students to empathise and think of possible solutions. Integrating the Year five RBT (Design and Technology) curriculum, students follow engineering design steps to produce their creations while English lessons involve simple role-plays and poems to enrich the project. By the end, students design various pet homes—for example, cages for cats, hamsters, and rabbits—complete with homemade food bowls and litter containers, using material selection justified by their learning. This three-week project generates excitement and engagement among the learners.

product. Maknuunah *et al*. (2023) quotes that Project-Based Learning, along with design thinking is applicable to any subject that requires problem-solving and project-based activities. This learning method uses syntax to assist students through cognitive building phases. Integrating project-based learning with design thinking can help address 21st-century learning concerns.

Encourage the Design Thinking Process

The design thinking approach enhances project-based learning by providing more detailed syntax and procedures. Using Project-Based Learning and design thinking can enhance students' learning experiences. Project-based learning, combined with a design thinking approach can be effective for learning focused on a specific project (Maknuunah *et al*., 2023).

Design thinking serves comparable aims as project-based learning. They guide kids to solve problems. Design thinking is a problem-solving approach that may be applied across various disciplines (Öztürk, 2021). Design thinking can be integrated into many learning strategies or methods. Design thinking may help 21st century learning methods by focusing on their fundamental objective. This is a Project-Based Learning strategy. From interview sessions, teachers said that:

"To plan a student STEM project, we take into account the steps in the design thinking process, namely, empathy, define, ideate, prototype, and test"- [T02]

"Starting a project with various stimuli that are closely related to students' lives is indeed effective in attracting students' interest with empathy. Creating projects keeps them interested while encouraging ideas and creativity. We need to be sensitive to the learning process until students produce products and test them" - [T07]

The role of design thinking approach here is to help the learning design itself, which use Project-Based Learning method so that the syntax of this learning method can be more detail and the steps are more specific. By applying the Project-Based Learning integrated with design thinking approach, students are expected to be helped in learning process. Project based learning integrated to design thinking approach can be used for learning with project as the main purpose. Integrating design thinking into Project-Based Learning could result in a new learning style that increases students' innovation (Öztürk, 2021). This integration focuses on the steps in the learning process. Table 4 below will provide information on the combination or integration of both phases.

Interdisciplinary by Collaborative

According to the findings, teachers use collaborative teaching approaches to achieve interdisciplinary integration of Science subjects with STEM or non-STEM group subjects. From interview sessions, teachers said that:

"We need to unpack and repack curriculum standards in the process of planning a project, we collaborate with Mathematics as STEM subject and non-STEM subject to find a project themes" - [T04]

"The project theme is chosen based on the Science topic that has been studied. Some of the knowledge and skills were from another subject familiar theme, it's to encourage students to make connections with other subjects we collaborate"- [T08]

The interview data indicates that teachers strategically "unpack and repack curriculum standards" to design projects, collaborating not only with Mathematics—considered a STEM subject—but also with non-STEM subjects. This collaborative approach helps them identify suitable themes aligned with the relevant Science topics, as well as complementary knowledge and skills from other disciplines. Consequently, students are encouraged to make connections across multiple subjects, fostering a more integrative learning experience. This clearly

Table 4: Integration syntax of PjBL and design thinking

Project-Based Learning	Design Thinking
Choosing topic	Empathize
Searching resources	Define
Organizing	
Developing thought	Ideate
Coordinating	Prototype
Reflection	Test
Follow up	

demonstrates that interdisciplinary STEM PjBL can be actualised through a collaborative strategy, as it integrates content and skills from both STEM and non-STEM subjects to address ill-structured problems.

Team teaching by comparison is when two or more teachers do what teachers do for a class, to plan, teach, assess, and take responsibility for all the students in the room, taking an equal share of responsibility, leadership, and accountability (Thousand *et al*., 2007). In an interdisciplinary team, teachers need to develop teamwork, communication skills, and positive attitudes toward interdisciplinary teaching (Wang *et al*., 2020) because most teachers feel they lose autonomy while investing time in decision-making and potentially have conflicts among each other on the team (Shapiro & Dempsey, 2001). Teacher choice, curriculum-driven design, and administrative support are necessary for interdisciplinary teams to be effective (Margot & Kettler, 2019).

Themes Align with Real-world Context

The interview data is supplemented by a document analysis, which demonstrates that primary school instructors adapt the project theme to the pupils' real-world contexts such as everyday life, environmental, and global challenges. It is consistent with the Sustainable Development Goal (SDG) 2030 agenda, which seeks to educate and engage the next generation in the pursuit of global sustainability (UNESCO, 2014). This is an endeavour to introduce youngsters to connecting their knowledge with the world's problems. From interview sessions, teachers said that:

> *"To start the project, the teacher will give related problems so that the students can apply their knowledge and skills in the topic to solve the problem. The problems always familiar to them. They can learn well when they feel relevance"*- [T02]

> *"We always choose project themes that related to students' daily life, nature,*

and society. In addition to being relevant to students, it also promotes sustainable development. It is very useful to increase student awareness as well"- [T05]

The interview data indicates that teachers ground student learning in easily identified relevant issues to ensure relevance and engagement. By choosing subjects pertinent to daily life, nature, and society, students can more readily associate classroom material with real-world issues and recognise the practical significance of what they are learning. Moreover, promoting sustainable development fosters awareness of the environment, encouraging learners to contemplate broader social effects and responsibilities while acquiring skills and knowledge. Table 5 presents data obtained from document assessments of teaching plans and project reports regarding the implementation of STEM PjBL in four sample schools for the entire academic year of 2022.

The analysis derived from data from both sources indicates that teachers execute PjBL STEM in accordance with the national curriculum, tailored to real-world themes, particularly those aligned with SDG topics, appropriate for the students' competency levels. The project is straightforward and can enhance cognitive and problem-solving abilities.

Meaningful Learning and Impactful Assessment

Students will be STEM literate if their learning experiences, whether formal, non-formal, or informal, consistently engage them in solving challenges relevant to real-world circumstances. Learning becomes relevant when the knowledge and skills given are applicable and meaningful to them. However, the real-world problem is complicated and must be addressed by combining knowledge and methodologies from other fields, resulting in a natural synthesis of approaches (EL-Deghaidy *et al.*, 2017). As a result, the students will collaborate in groups to address the challenge cooperatively, using

Table 5: Data collected on STEM PjBL implementation of four sample schools from document review such as teaching plan and project reports

School Code	Term of Implementation	Total Number of Projects Executed in A Year (2 Terms)	Student	Project Title	Sustainable Development Themes that Can be Related	Science Year 5 Syllabus: Content Standard
S1	1	3	Year 3	Healthy Plate	SDG3: Good Health and Well-being	3.2 Food Pyramid
			Year 4	My Room Decor	-	8.1 Basic Sources of Materials
			Year 6	From Trash to Cash	SDG12: Responsible Consumption and Production	9.1 Waste Management
S1	2	4	Year 4	Light in the Dark	SDG11: Sustainable Cities and Communities	5.0 Characteristic of Light
			Year 5	Fruit Plucker	SDG12: Responsible Consumption and Production	8.0 Materials and Their Characteristic
			Year 5	Organic Plant	SDG12: Responsible Consumption and Production	5.1 Preservation and Conservation for the Balance of Nature
			Year 6	Hydroponic Pond	SDG11: Sustainable Cities and Communities	4.1 Interaction between living Creature
S2	1	3	Year 3	Organic Pet Food	SDG12: Responsible Consumption and Production	4.1 Animal Food and Eating Habit
			Year 4	Pet Cage	SDG11: Sustainable Cities and Communities	8.0 Materials and Their Characteristic
			Year 6	Food Preservation	-	8.2 Food Preservation
S2	2	3	Year 4	Solar Cooker	SDG7: Affordable and Clean Energy	7.0 Energy 7.2 Renewable Energy
			Year 5	Temperature Sensing Strip	SDG3: Good Health and Well-being	6.1 Heat and Temperature
			Year 6	Commercial Food Products	SDG12: Responsible Consumption and Production	8.0 Food Preservation Technology

			Year	Project	SDG	Science Content
S3	1	4	Year 4	Insect Repellent Herbs	SDG6: Clean Water and Sanitation	4.1 Interaction between Animals
			Year 5	Reduce Our Bills Campaign	SDG12: Responsible Consumption and Production	5.3 Equipment Operation Safety and Electricity Saving
			Year 6	Protect Our Rivers and Seas	SDG14: Life Below Water	5.0 Food Preservation Technology
S3	2	2	Year 5	Saving Water for Our Future	SDG11: Sustainable Cities and Communities	8.2 Change of State of Matter for Water
			Year 6	Recreation Park for Everyone	SDG10: Reduced Inequalities	12.1 Stability and Strength of Objects and Constructions
S4	1	2	Year 3	Row Row Row the Boat	SDG12: Responsible Consumption and Production	7.1 Objects or Substances Denser or Less Dense than Water
			Year 5	Mini Colony	-	3.1 Survival of Animal Species
S4	2	2	Year 4	Electricity Saving Bulbs	SDG7: Affordable and Clean Energy	7.1 Sources of Energy
			Year 6	Community Vegetable Garden	SDG2: Zero Hunger	4.2 Interaction between Plants

an interdisciplinary approach to create an innovative solution. From interview sessions, teachers said that:

> *"Projects are the application of knowledge, skills, and values they have learned, therefore, activities that encourage critical and creative thinking to produce products will be implemented by teachers. Students can produce products and justify their choices"- [T03]*

> *"Activities carried out lead to learning outcomes, as well as assessment that occurs throughout learning"- [T06]*

> *"Assessment in PjBL is called authentic assessment, we use an assessment rubric throughout learning" - [T07]*

Teachers feel that PjBL assignments can be successfully implemented when comprehensive preparation is carried out. Teachers are pleased with the students' participation and development on the STEM PjBL assignment. The interview revealed that teachers saw PjBL as an appropriate methodology for STEM T&L. Teachers can apply STEM T&L using the STEM T&L features (MoE, 2016) and the Integrated STEM approach framework (MoE, 2020). This suggests that in student learning, teachers agreed that PjBL should be done twice a year based on relevant themes. The document review and interviews concluded that the interdisciplinary PjBL STEM T&L implemented in school is shown in the flow chart in Figure 3 which similar with project-based learning approach by George Lucas Educational Foundation (Curtis, 2002). Figure 3 depicts the flow of interdisciplinary PjBL STEM practiced in elementary schools, summarised by teacher interviews and document evaluation.

Challenges Facing by Teachers of Interdisciplinary STEM PjBL Implementation in Primary Level Lesson

Although teachers have demonstrated their ability to implement interdisciplinary STEM PjBL, the data indicate that several challenges arise during project execution. These challenges were identified through interviews and corroborated by document review findings.

RQ2: How are the Challenges Facing by Teachers of Interdisciplinary STEM PjBL Implementation in Primary Level Lesson?

Based on interviews with all responders, numerous challenges of multidisciplinary STEM PjBL implementation have been highlighted as barriers namely, difficulty finding a theme that fits the learning standard, adaptation of students with various abilities, teachers are less proficient at implementing PjBL, and implementation of interdisciplinary STEM PjBL is quite time-consuming.
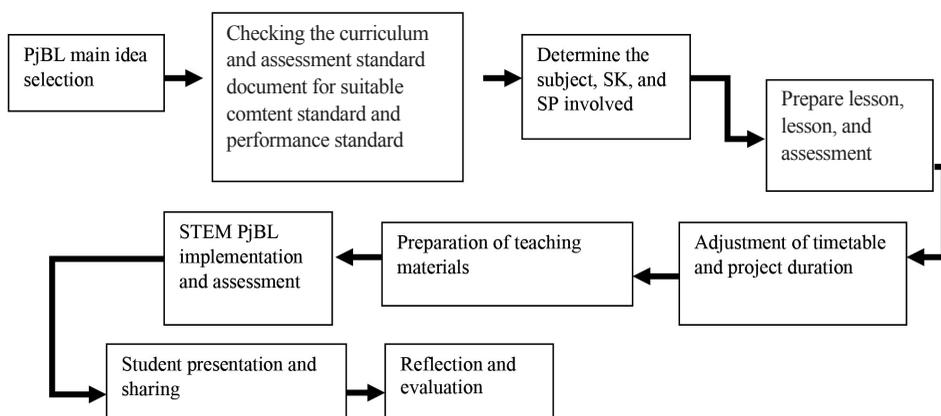

Figure 3: Flow chart of the practices interdisciplinary PjBL STEM implementation in primary schools

Difficulty Finding A Theme that Fits the Learning Standard

As for the planning, there were issues to select the key ideas with minimal or no content integration with the program requirements. In addition, teachers need to produce a STEM PjBL that involves real-world problems, which were found to be quite complicated to plan. From interview sessions, teachers said that:

> *"The issue of program planning is more on the stage of disassembling the SK (content standard) and SP (performance standard) that do not have the same idea or content, which directly aligned. It causes problems for integration to occur" - [T02]*

> *"Skills-based subjects such as Malay, English, and Mathematics are easier to integrate for the interdisciplinary T&L than content-based subjects because it is necessary to find the right theme" - [T05]*

> *"Skills-based subjects such as Malay, English, and Mathematics are easier to integrate for the interdisciplinary T&L than content-based subjects because it is necessary to find the right theme. But when there is collaboration, integration can be realised"- [T08]*

The process of identifying key ideas and integrating them into a cohesive STEM PjBL is challenging, particularly when curriculum standards (SK and SP) do not overlap. T02 notes that disassembling these standards to find complementary objectives often reveals gaps that impede integration. Real-world problem contexts add complexity (Nadelson *et al.*, 2013). Teachers find content-heavy subjects harder to merge than skill-based areas like Mathematics, Malay, or English (Bybee, 2013). As T05 and T08 note, thoughtful theme selection ensures subject-specific depth and authenticity (Darling-Hammond *et al.*, 2020). This approach demands considerable expertise, collaboration, and planning time (Margot & Kettler, 2019).

Professional development is also vital, helping teachers navigate curriculum disassembly and reassembly to balance knowledge, skills, and application (Shernoff *et al.*, 2017). Overall, crafting interdisciplinary STEM PjBL requires careful design and support to foster meaningful, integrative learning experiences. Hence, teachers need structured guidance to effectively optimise student outcomes in integrated primary schools.

Adaptation of Students with Various Abilities

Pupils consist of various levels of ability. Thus, teachers need to give more guidance to weak students to trigger empathy and creativity. Open-response questions have not been regularly used in teacher discussions. They used more guided inquiry questions to solve problems. Groups of teacher's response about implementation of PjBL:

> *"Weak and average students are really interested in learning if the activities are hands-on, I can attract students to learn with PjBL"- [T03]*

> *"I found that my mediocre students like STEM PjBL activities, maybe because its hands-on, they can relate the problems to their experiences, and they are actively involved in the discussion rather to other methods"- [T06]*

> *"Weak and average students are really interested in learning if the activities are hands-on, I can attract students to learn with PjBL"- [T07]*

The teacher also stated that PjBL allows assessment to be implemented for students through an interdisciplinary approach. This is because students are given non-routine problems involving the daily life environment and society in line with the student's mastery level indicator. This aligned with STEM Lesson Essentials for Grades 3-8 (Vasquez *et al.*, 2013).

Teachers Are Less Proficient at Implementing PjBL

PjBL planning requires the teacher's understanding, but they seem to not fully understand it, this causes integration to be difficult to implement according to the knowledge and skills. This is because workshops and training are only attended by two school teacher representatives. Data also identified that they only attend average one training on STEM education program. The implementation of professional development training is insufficient, causing most teachers not to understand the integration concept well. Whereas, for program that involve technology integration, teachers' skills in developing digital technology projects and activities are moderate to low. This was because teachers lack skills in technology and engineering.

> *"We are not trained with STEM integration, no short-term training either. Indeed, we only do it according to our understanding"* - [T01]

> *"When we first implemented PjBL STEM, we were blur. This is because we need to understand the concept of STEM approach, PjBL process, and interdisciplinary integration. It is difficult for us without training and guidance"* - [T05]

The findings clearly demonstrate that teachers are unprepared for the implementation of STEM PjBL. Teacher limitations are more focused on designing student projects that enhance meaningful learning.

Implementation of Interdisciplinary STEM PjBL is Quite Time-consuming

From the interviews, the interdisciplinary approach affected time and annual planning. The interviews found that teachers can implement content integration for curriculum planning well, but the process of preparing unit lessons and group PjBL lessons takes a long time. Teachers need to prepare teaching materials and project materials in the implementation of STEM PjBL. Based on document review, also show that Science and Mathematics are the main subjects involved in STEM PjBL (Table 2). While all projects involve non-STEM subject to support skills and content on solve ill-structure problems. From interview sessions, teachers said that:

> *"PjBL can be implemented for 2 or a maximum of 3 times a year depending on the topic. But it can't be more than that because the time required can disrupt the entire annual teaching plan"* - [T03]

> *"I like to collaborate with other teachers to plan the T&L because some have the same lesson content but it's taking a lot of time"* - [T07]

The average duration for the PjBL task planning took one to two weeks. The average time taken to prepare teaching materials was less than a week. While average duration completing project including teacher's preparation three to four weeks. According to the weekly time table, only two hours per week are allocated for Science and Mathematics subject, which is clearly insufficient.

However, the teacher stated that the approach was also beneficial to the T&L practice at school. Teachers find it difficult to integrate with curriculum standards that have limited similar content and skills or match with project themes during the planning stage. Collaboration allows for a more structured and achievable interdisciplinary project (Kelley *et al*., 2021). As the summary of all the challenges that were faced by teachers to implement interdisciplinary STEM PjBL in primary school, due to several factors:

(a) Curriculum Constraints: Integrating STEM into the national curriculum is challenging because not all learning standards are suitable for integration into STEM projects. The national curriculum is typically

designed with a strict and specific structure. Each subject has clear and separate learning objectives, making it difficult to integrate different subjects into a holistic STEM project (Mohtar *et al.*, 2006).

(b) Different Learning Standards: Not all learning standards from each subject can be adapted for STEM projects. Some standards are very specific and in-depth within the context of a particular subject, making it difficult to link with concepts from other subjects without sacrificing depth or accuracy (Bybee, 2013).

(c) Lack of Resources and Support: Integrating STEM requires sufficient resources such as equipment, materials, and teacher training. Schools may not have the necessary resources to conduct effective and meaningful STEM projects (Nadelson *et al.*, 2013).

(d) Teacher Expertise: Teachers are usually experts in specific subjects and may lack knowledge or confidence in teaching outside their area of expertise. To integrate STEM, teachers need to collaborate and may require additional training to understand how to connect concepts from various disciplines (Shernoff *et al*., 2017).

(e) Assessment and Testing: An assessment system focused on individual academic achievement in specific subjects can make it difficult to apply an integrated approach. STEM projects often require more qualitative assessments that focus on process and collaboration, which may not align with standard test formats (English, 2016).

Overall, while integrating STEM into the national curriculum offers many benefits, it requires careful planning, strong support from all involved parties, and adjustments to more flexible teaching and assessment methods. Furthermore, integrating sustainable development topics into STEM projects aligns with the broader goals of Education for Sustainable Development (ESD), which seeks to empower learners to contribute to a more sustainable future (Chong, 2019). By fostering sustainability literacy and environmental awareness among students, STEM education can play a vital role in building a generation of responsible global citizens who are equipped to address pressing sustainability challenges.

Conclusions

Overall, this study reveals that interdisciplinary STEM Project-Based Learning (PjBL) in primary schools is implemented through problem-oriented projects based aligned with the national curriculum, real-world contexts, and collaborative teaching approaches; however, challenges persist, including identifying suitable themes, addressing diverse students' abilities, enhancing teacher proficiency, and managing time constraints. These findings imply that a strategic, well-supported, and skilfully coordinated approach can maximise the positive impact of interdisciplinary STEM PjBL, fostering essential 21st-century skills such collaboration, critical thinking, creativity, and problem-solving among students. Furthermore, the study underscores the need for robust teacher training and professional development to strengthen teachers' capacities in designing and delivering interdisciplinary STEM PjBL activities, as well as in integrating sustainable development goals.

This study contributes to the existing body of knowledge in STEM education, particularly at the primary level, by highlighting the interdisciplinary application of Project-Based Learning (PjBL) and its efficacy in advancing sustainability education. It emphasises how PjBL integrates various STEM disciplines to create cohesive and engaging learning experiences that foster critical thinking and problem-solving skills among young learners. Schools and policymakers should promote collaborative, flexible curricula, and assessment methods to accommodate this holistic approach. Future research could involve larger sample sizes and multiple school settings to expand the generalizability of the findings. Longitudinal

studies examining how extended exposure to interdisciplinary STEM PjBL shapes students' academic achievement and career interest would be valuable. Additionally, investigations into the optimal balance between content depth and interdisciplinary breadth, as well as innovative assessment techniqes tailored to PjBL would further enhance the quality and sustainability of STEM education in primary schools.

Acknowledgements

Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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