English Medium Instruction Lessons in a Science Class for Primary School Students

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Abstract

This mixed-methods study investigated the effects of integrating Merrill's First Principles of Instruction (FPI), the English-for-Teaching (EfT) framework, and Inquiry-Based Learning (IBL) in an English Medium Instruction (EMI) primary science classroom in Thailand. The study examined their impact on Grade 5 students' science process skills (SPS) and science vocabulary (SV) achievement. Thirty students were selected through cluster sampling from a private school in Eastern Thailand. Six EMI science lessons were designed by embedding EfT principles within FPI's task-centered instructional cycle and structuring inquiry tasks through IBL. Quantitative data were collected through pretest-posttest assessments, while qualitative data were obtained from classroom observations and researcher reflections. Paired-samples t-tests revealed a statistically significant improvement in SPS and a more moderate but significant improvement in SV. Thematic analysis indicated enhanced scientific reasoning, engagement, and contextual vocabulary use, although challenges in lexical precision persisted. The findings suggest that integrating instructional design of FPI, disciplinary inquiry (IBL), and teacher language mediation (EfT) can support dual-domain development in EMI primary science classrooms. This study contributes empirical evidence to the under-researched area of primary EMI in Thailand and offers transferable pedagogical implications for similar EFL contexts.

Keywords: EMI lesson, primary science, learning achievement, first principles of instruction, English for teaching

Introduction

English Medium Instruction (EMI) has become an increasingly prevalent global phenomenon, driven by the worldwide proliferation of internationalization programs in higher education and a growing demand for English proficiency (Gilanyi et al., 2023). Research since 2005 indicates a rapid expansion in the field of EMI, with significant implications for English language learning and outcomes (Macaro, 2018). EMI has been shown to positively affect student learning outcomes and academic achievement, particularly in content areas like mathematics and science, by providing opportunities to learn and practice the language in authentic contexts (Block, 2021). However, bridging the gap between language and content knowledge remains a persistent challenge, and research on how to effectively integrate English language instruction into scientific teaching is still limited (Bonello, 2020; Pun et al., 2024).

In non-English speaking nations, EMI is frequently implemented to enhance students' language proficiency and prepare them for the global workforce. This trend is particularly prominent across Asia and Southeast Asia. Within the Thai educational context, English is widely used as the medium of instruction in private schools (Liu, 2022; Widiawati & Savski, 2023). The Thai Ministry of Education (MOE) has emphasized the necessity of improving Thai learners' language competence by introducing English programs at an early age to meet the demands of the ASEAN community. Consequently, the Thai government has been actively promoting EMI to cultivate a more English-proficient workforce prepared for the demands of globalization (Galloway & Sahan, 2021). Despite this growth, challenges persist in promoting deeper learning within EMI classrooms and fully understanding its overall educational impact (Zhou et al., 2025).

The quality of education is intrinsically linked to the quality of classroom instruction. A significant issue in EMI pedagogy is the challenge of achieving optimal learning outcomes for students. Much of the previous research has focused on EMI practices in higher education (Galloway & Sahan, 2021). In contrast, relatively little attention has been paid to the EMI context in primary schools, especially within Thailand.

Inquiry-Based Learning (IBL) is widely recognized as an effective pedagogical approach in science education. The 5E model, a key IBL framework, enables students to actively explore and discover scientific concepts and principles (Kulapian et al., 2023). Similarly, Merrill's First Principles of Instruction (FPI) have been shown to positively impact student learning and engagement, leading to enhanced learning effectiveness, increased motivation, and greater opportunities for knowledge application and integration across diverse disciplines (Truong et al., 2019). However, the participants in many of these studies were at the undergraduate level, and current EMI research has devoted little attention to the application of FPI (Hao & Yamada, 2021). Therefore, research involving elementary-level learners is crucial. Concurrently, the English-for-Teaching (EfT) framework within English for Specific Purposes (ESP) has garnered significant attention. Various studies have explored the

application of EfT courses to improve English proficiency (Basturkmen, 2025). Nevertheless, there is a paucity of research on the application of the EfT framework in primary EMI settings. This gap in the literature motivated the development of EMI lesson plans for primary science, grounded in the EfT framework, First Principles of Instruction, and Inquiry-Based Learning theories.

This study aims to investigate the effectiveness of implementing these EMI lesson plans in a primary science classroom and to determine their impact on students' science process skills and science vocabulary achievement. The research questions are as follows: (1) To what extent do the EMI lessons improve primary school students' science process skill achievement? (2) To what extent do the EMI lessons improve primary school students' science vocabulary achievement?

This study was guided by three theoretical frameworks. First, Merrill's (2002) FPI provided the theoretical foundation for designing the EMI lesson plans. Second, the lessons were structured according to the EfT framework's three functional areas (Freeman et al., 2015): managing the classroom to maintain an engaging, task-centered environment; understanding and communicating lesson content using science-specific language; and assessing student progress through oral feedback. Third, drawing on the inquiry-based learning theory proposed by Bybee et al. (2005), the IBL framework guided the design of key tasks within the six science lesson plans.

Although FPI, EfT, and IBL have been examined independently in previous studies, limited research has explored their integrated application within EMI primary science contexts. FPI provides a structured instructional design model emphasizing task-centered learning and knowledge application (Lo et al., 2018; Yorganci, 2020). IBL complements this by operationalising scientific inquiry through structured exploration. EfT, meanwhile, focuses on teacher language use to scaffold content comprehension and classroom interaction (Freeman et al., 2015). The integration of these frameworks addresses three essential dimensions of EMI pedagogy: instructional design (FPI), disciplinary inquiry (IBL), and language mediation (EfT). However, empirical evidence demonstrating their combined effect at the primary level remains scarce, particularly in Southeast Asian contexts. This study seeks to address this gap.

The conceptual framework provided a comprehensive foundation of the key factors of designing this EMI lesson plan for primary science class. By embedding the EfT framework into the FPI and IBL theories, in order to develop science process skills and science vocabulary achievement as illustrated in Figure 1.

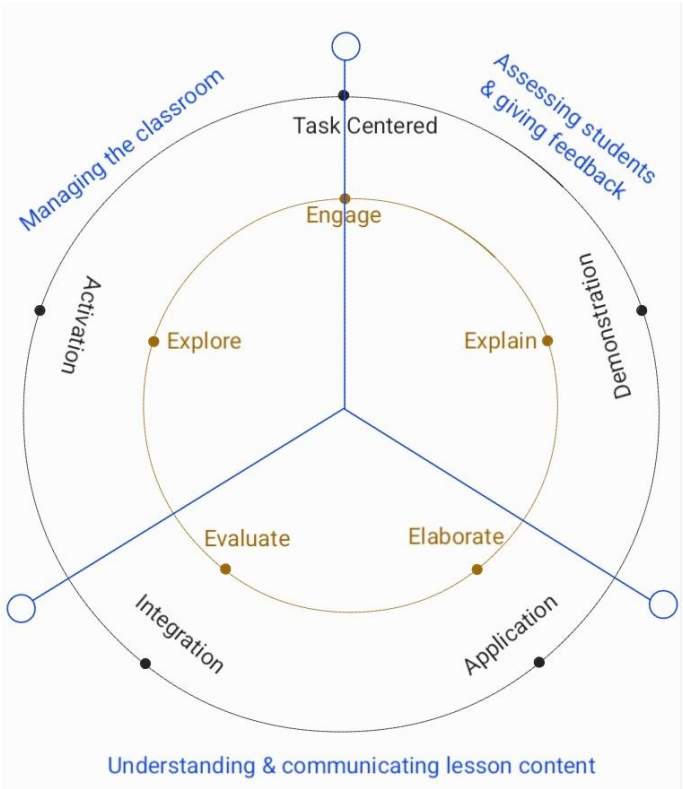


Figure 1. *Integration of Theoretical Frameworks for EMI Lesson Design*

Literature Review

EMI in Thai Primary Education

Although EMI has expanded rapidly in Thai higher education, empirical research at the primary level remains limited. In private Thai schools, EMI is often positioned as a competitive educational model; however, the effectiveness of EMI depends not merely on language exposure but on pedagogical integration of content and language learning. Without structured instructional frameworks, EMI risks becoming linguistically demanding without ensuring conceptual depth.

Science Process Skills in EMI Contexts

Science Process Skills (SPS) refer to cognitive and procedural abilities essential to scientific inquiry, including observing, classifying, predicting, inferring, and interpreting data. In EMI classrooms, these skills must be expressed through a second language, creating dual cognitive-linguistic demands. Therefore, pedagogical design must ensure that language barriers do not inhibit scientific reasoning.

Science Vocabulary Development and Vocabulary Knowledge Framework

Science Vocabulary (SV) includes discipline-specific terminology and general academic language required for scientific explanation. Vocabulary knowledge involves three dimensions: form,

meaning, and use (Nation & Meara, 2013). In EMI contexts, learners must not only understand scientific terms but also accurately produce them in oral and written discourse. Prior research in EMI science settings indicates that vocabulary development often lags behind conceptual understanding, particularly in productive use (Hong & Basturkmen, 2020). This underscores the importance of explicit vocabulary scaffolding within EMI science instruction.

Instructional Frameworks Supporting EMI Science

Merrill's FPI emphasize task-centered learning structured through activation, demonstration, application, and integration. The IBL, particularly the 5E model, promotes exploration and scientific reasoning processes aligned with SPS development. The EfT framework focuses on teachers' classroom language mediation, ensuring accessible content explanation and interactive discourse.

Rationale for Integrating FPI, EfT, and IBL

Although these frameworks have been explored independently, limited research has examined their integrated application in primary EMI science classrooms. FPI structures instructional sequencing, IBL operationalizes scientific inquiry, and EfT supports linguistic mediation. Together, they address instructional design, disciplinary inquiry, and language scaffolding three core dimensions of EMI pedagogy. Empirical evidence demonstrating how such integration influences both SPS and SV achievement at the primary level in Thailand remains scarce. This study addresses this gap.

EMI in Thailand and Teaching Science in English for ESL Students

Research on English Medium Instruction (EMI) in Thailand has increasingly focused on the perspectives and practices of educators and learners. Studies have underscored the importance of investigating teacher and student beliefs, which significantly impact both English proficiency and content acquisition (Macaro, 2018). In the Thai context, teachers often express mixed perceptions of EMI, influenced by their own language proficiency and their students' perceived readiness (Handayani et al., 2022; Penthisarn & Phusawisot, 2021). This is further complicated by the need for effective pedagogical strategies; for instance, research indicates that categorizing teacher pedagogies based on language use and classroom interaction is crucial (Galloway & Rose, 2021). To promote effective science learning, scholars argue that employing targeted questioning techniques and pre-class activities is key to developing students' analytical skills (Pun et al., 2022). While integrating EMI with established curricula can enhance academic performance (Rachmajanti et al., 2023), these studies collectively highlight the complexities of implementing science in an EMI context. They reveal a critical need for further research into the intricate relationship between language and content learning, particularly within Thai science classrooms.

Conceptualizing Science Process Skills and Science Vocabulary in EMI Contexts

Science Process Skills (SPS) refer to the cognitive and procedural abilities required for scientific inquiry, including observing, classifying, inferring, predicting, experimenting, and interpreting data (Gunawan et al., 2019). SPS are foundational to scientific literacy, as they enable learners to engage in evidence-based reasoning rather than passive knowledge acquisition. In EMI contexts, SPS development may be influenced by learners' linguistic proficiency, as scientific reasoning must be articulated through English (An & Thomas, 2021).

The SV, in contrast, refers to discipline-specific lexical knowledge required to comprehend and express scientific concepts. Following Nation and Meara' s (2013) framework, vocabulary knowledge includes three dimensions: form (pronunciation/spelling), meaning (conceptual understanding), and use (grammatical and contextual appropriateness). In EMI classrooms, SV becomes both a linguistic and cognitive challenge, as learners must simultaneously construct conceptual understanding and linguistic precision (Henschel et al., 2023).

While SPS and SV are conceptually distinct, they are interdependent in EMI science learning. Scientific reasoning requires accurate conceptual vocabulary, and vocabulary knowledge deepens through inquiry-based scientific engagement. Therefore, instructional frameworks that simultaneously support cognitive task engagement (FPI), inquiry structuring (IBL), and language mediation (EfT) may facilitate dual-domain development.

Current Research on Students' Scientific and Vocabulary Achievement in Science EMI Context

Primary science education fundamentally aims to develop students' science process skills (SPS), such as observation, experimentation, and critical reasoning, which are essential for scientific literacy. Research consistently demonstrates that incorporating experiential, inquiry-based, and collaborative learning strategies enhances SPS achievement (Damopolii et al., 2019). Concurrently, vocabulary is a foundational building block for comprehension, especially in science classrooms with mixed language abilities (Van Orman et al., 2021). Academic and technical vocabulary are recognized as the primary language demands in science, and a robust framework for vocabulary knowledge encompasses form, meaning, and use. The reciprocal relationship between science knowledge and science vocabulary is well-established (Henschel et al., 2023), underscoring vocabulary as an indispensable component of content learning for L2 and EFL students. However, a significant research gap persists. Current studies on vocabulary in science are predominantly conducted with young native English speakers in general language classrooms (Van Orman et al., 2021), while research explicitly addressing science vocabulary in mixed-proficiency EMI settings remains limited.

Methodology

Research Design

This study employed an embedded mixed-methods design to comprehensively analyze the impact of EMI lesson plans on the SPS and the SV achievement in a Grade 5 science classroom. Quantitative data were collected via pre- and posttest assessments to measure changes in student achievement. Qualitative data were gathered through classroom observations, audio recordings, and researcher reflections to provide insights into student interactions, vocabulary proficiency, and classroom behaviors during the intervention.

Context and Participants

The study was conducted in a private school in Chon Buri province, Thailand, during the second semester of the 2023 academic year. The target population comprised all Grade 5 students enrolled in the EMI science subject courses. Using cluster sampling, one intact class of 30 students (15 females, 15 males), aged 10–12, was selected from the eight available Grade 5 sections.

Grade 5 was selected because students at this level possess emerging abstract reasoning abilities necessary for inquiry-based science learning while still requiring structured linguistic scaffolding in EMI settings. This developmental stage makes it particularly relevant for examining dual-domain (content-language) instruction.

Cluster sampling was employed due to administrative constraints and the intact class structure of the school. While this approach enhances ecological validity by preserving natural classroom dynamics, it may limit generalizability and introduce group-specific effects. This limitation is acknowledged in the interpretation of findings.

Research Instruments

Pretest and Posttest

Assessments were developed to measure student achievement related to the unit “Living Things in the Environment.” Each test comprised 22 items: 20 objective questions (4 marks each) and 2 subjective questions (10 marks each), categorized as factual, inferential, vocabulary, or interpretive. SPS achievement was evaluated across all 22 items, while SV achievement was specifically measured using seven items from the factual and vocabulary categories

Lesson Plans

The intervention consisted of six EMI lesson plans designed by integrating the EfT framework, Merrill’s FPI, and the IBL theory. The lessons were task-centered, following the activation, demonstration, application, and integration phases of FPI. The EfT framework guided classroom

management, content communication using science-specific language, and formative assessment through oral feedback. IBL principles structured key tasks to promote scientific inquiry.

Vocabulary instruction followed Nation and Meara's (2013) three-dimensional framework of form, meaning, and use. Each lesson incorporated:

(1) meaning-focused input through visual aids and contextual explanation;

(2) form-focused attention through pronunciation modeling and spelling clarification;

(3) meaning-focused output through guided discussions and collaborative tasks requiring active vocabulary use.

The whole teaching schedule of EMI lesson plans and the EMI lesson ideas were presented as Table 1 and Figure 2 below.

Table 1.

Teaching Schedule of EMI Lesson Plans

Session	Instruction List	Period	Note
1	The Environment (Habitats)	1	50 minutes
2	Shelter and Protection	1	50 minutes
3	Herbivores, Carnivores and Omnivores	1	50 minutes
4	Living things get energy from their environment	1	50 minutes
5	Food Chain	1	50 minutes
6	Food Web and Decomposers	1	50 minutes

Classroom Observation and Researcher's Reflection

An observation form was used to systematically record data on classroom atmosphere, student performance of science process skills, interaction accuracy, communication fluency, and proficiency with technical vocabulary. Researcher reflections were documented after each session to capture contextual nuances and emerging patterns.

Validity and Reliability of Instruments

The instruments' validity was established through a review by three experts using the Item Objective Congruence Index (IOC). Following revisions based on their feedback, the pretest-posttest and lesson plans achieved IOC scores of 0.70 and 0.75, respectively, indicating acceptable validity. A subsequent pilot study with 30 students from a similar background was conducted to assess reliability. The internal consistency of the pretest-posttest, measured by Cronbach's alpha, was .85, demonstrating high reliability.

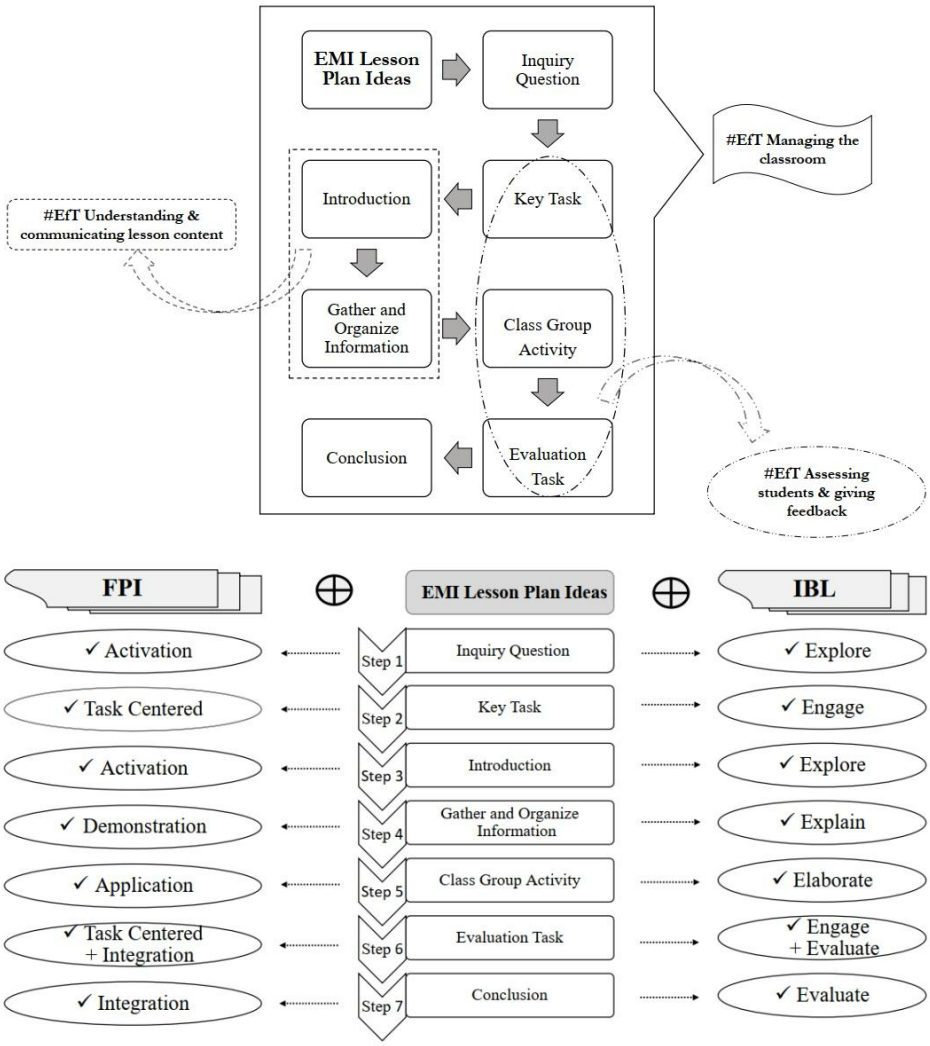


Figure 2. *Integrated Design of the EMI Lesson Plan*

Data Collection

The study commenced with the administration of the pretest to all 30 participants. This was followed by a one-month intervention period, during which the six EMI lessons were implemented. Each session was audio-recorded, and the researcher completed observation notes immediately after class. The study concluded with the administration of the posttest.

Data Analysis

Quantitative data from the pretest-posttest were analyzed using SPSS Statistics 26. Descriptive statistics were calculated, and a paired-samples t-test was performed to compare the mean scores. Qualitative data, including audio recordings and observation notes, were analyzed using inductive thematic analysis (Toyon, 2021). Transcripts of teacher-student interactions were coded and thematically analyzed, focusing on classroom atmosphere, science process skills, interaction accuracy, communication fluency, and the use of technical vocabulary.

Ethical Consideration

The study received ethical approval from the Research Ethics Committee of Burapha University (No: G-HU292/2566). Prior to commencement, informed consent was obtained from the school principal, parents, and all student participants. Parents and students were provided with detailed information regarding the study's purpose, procedures, voluntary nature, and confidentiality measures.

Results

This study addressed two research questions concerning the effects of integrating FPI, EfT, and IBL in an EMI primary science classroom on students' SPS and SV achievement. Quantitative results from pretest-posttest comparisons are presented first, followed by qualitative findings derived from classroom observations and researcher reflections. The results are shown in Figure 3 below.

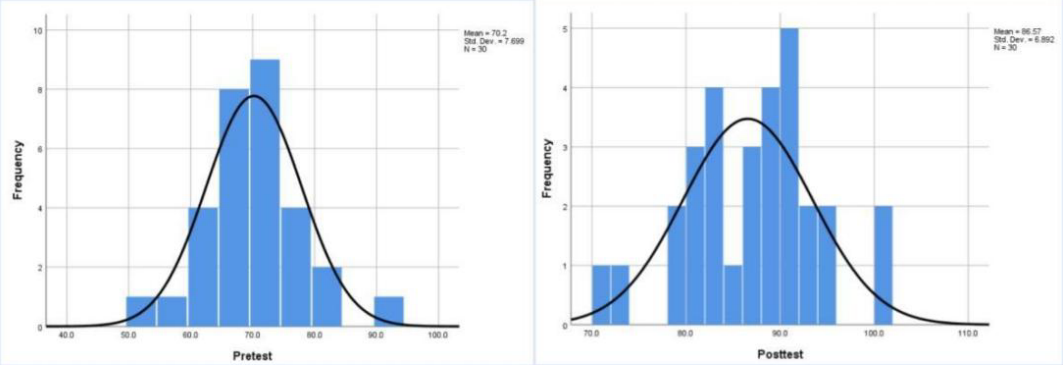


Figure 3. *Histograms of Pretest and Posttest Results*

RQ1: To what extent do EMI lessons improve primary school student's science process skill achievement?

Quantitative Results

A paired-samples *t*-test revealed a statistically significant increase in SPS achievement from pretest (M = 70.20, SD = 7.70) to posttest (M = 86.57, SD = 6.89), $t(29)$ = -19.98, $p < .001$. The substantial mean difference indicates that the EMI intervention had a strong positive effect on students' science process skills. The improvement suggests that the structured task-centered design and inquiry-based activities effectively supported the development of students' abilities in observation, classification, inference, and reasoning, as shown in Table 2.

Table 2.

Comparison between Pretest and Posttest of the SPS items

Group	*N*	*M*	*SD*	Mean diff.	*SD*	*t*-value	*df*	*p*-value
Pretest	30	70.20	7.70	-16.37	4.50	-19.89	29	.000
Posttest		86.57	6.89					

Qualitative Results

The qualitative findings corroborated the quantitative improvement and revealed noticeable development in students' scientific reasoning and analytical abilities.

During inquiry-based activities, students demonstrated increased competence in identifying relationships between organisms and explaining causal mechanisms. For example, when analyzing food chains, students correctly identified producers, primary consumers, and secondary consumers, and articulated the directional flow of energy. Rather than merely recalling definitions, they explained ecological relationships in their own words, indicating deeper conceptual understanding.

In classification tasks, students justified their reasoning by linking observable characteristics to scientific categories. When discussing animals with flat teeth, students connected anatomical features to dietary classification, demonstrating inferential thinking rather than simple memorization. These responses reflected the application phase of FPI, where students actively transferred learned knowledge to problem-solving contexts.

Collaborative design tasks further illustrated the development of higher-order thinking. Students negotiated ideas, evaluated environmental constraints, and proposed structural solutions for shelter construction. Observational data indicated increased engagement, sustained task focus, and productive peer interaction throughout the intervention period.

Overall, the integration of task-centered instruction (FPI) and structured inquiry processes (IBL), supported by teacher language scaffolding (EfT), appeared to create a cognitively stimulating environment that strengthened science process skills.

RQ2: To what extent do EMI lessons improve primary school student's science vocabulary achievement?

Quantitative Results

A paired-samples *t*-test showed a statistically significant improvement in science vocabulary achievement from pretest ($M = 12.27$, $SD = 5.75$) to posttest ($M = 16.13$, $SD = 5.80$), $t(29) = 7.37$, $p < .001$. Although statistically significant, the magnitude of improvement was smaller compared to SPS gains.

This suggests that vocabulary development occurred during the intervention but may require longer-term or more intensive reinforcement for greater effect. As presented in Table 3.

Table 3.

Comparison between Pretest and Posttest of the SV items

Group	*N*	*M*	*SD*	Mean diff.	*SD*	*t*-value	*df*	*p*-value
Pretest	30	12.27	5.75	-3.87	2.87	-7.37	29	.000
Posttest		16.13	5.80					

Qualitative Results

The qualitative findings revealed a more nuanced pattern in science vocabulary development. Students demonstrated increased confidence in using scientific terminology during classroom discussions and inquiry tasks. Terms such as “herbivore,” “carnivore,” “producer,” and “food chain” were used more frequently and in appropriate contextual explanations.

Students were also able to extend vocabulary use beyond textbook examples, applying terms to hypothetical or exploratory discussions. This indicates that vocabulary learning was not limited to rote memorization but was integrated into conceptual reasoning.

However, challenges persisted in lexical precision and productive accuracy. Students occasionally relied on informal or descriptive phrases (e.g., “plant-eater animal”) before recalling the appropriate scientific term. In other cases, approximations were used before corrective feedback was provided. Written responses in the posttest demonstrated improved logical sequencing and expanded vocabulary use; nevertheless, spelling errors and inconsistent formal terminology indicated that productive mastery remained incomplete.

These findings suggest a distinction between receptive and contextual understanding of vocabulary and the precise, accurate use of terminology in academic writing. While the EMI lessons effectively supported vocabulary comprehension and oral application, further reinforcement may be required to consolidate written accuracy and lexical precision.

An analysis of pretest and posttest samples (see Figure 4) further illustrated these findings. Pretest responses often featured incorrect logical flows and a limited vocabulary drawn directly from the prompts. Posttest responses showed improved logical sequencing and the inclusion of relevant scientific terms (e.g., “autotrophs”). However, persistent spelling errors (e.g., “autotrophs”) indicated that while conceptual understanding and vocabulary breadth grew, precision in written expression remained a challenge.

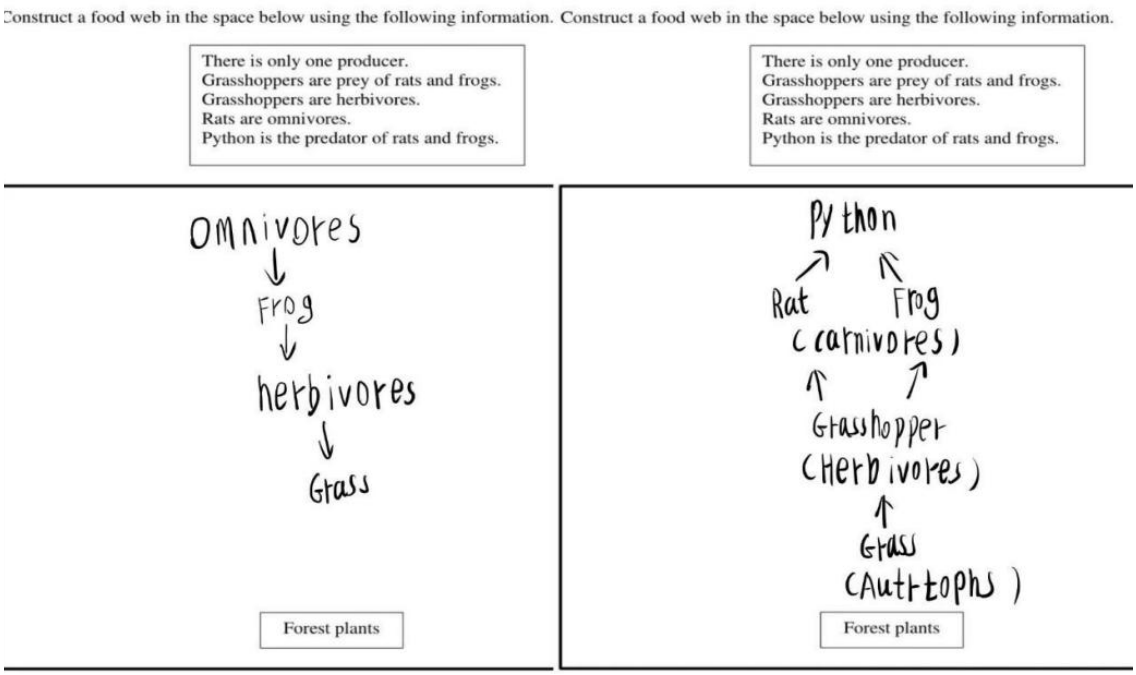


Figure 4. *Screenshot of the Sample Student Performance in Pre and Posttests*

Summary of Findings

The results demonstrate that the integrated EMI instructional model produced strong gains in science process skills and moderate but significant gains in science vocabulary achievement. The data suggest that the combined application of FPI, IBL, and EfT supported dual-domain development by simultaneously fostering scientific reasoning and contextual vocabulary use. However, the disparity between conceptual vocabulary growth and lexical precision highlights the complexity of language development in EMI primary classrooms.

Discussion

This study's findings demonstrate the effectiveness of an EMI pedagogical model that integrates Merrill's FPI, the EfT framework, and the IBL. The significant improvement in students' science process skills (SPS) can be attributed to the synergistic effect of FPI's task-centered approach and IBL's emphasis on active exploration. This aligns with prior research affirming FPI's efficacy in STEM disciplines (Truong et al., 2019) and IBL's role in fostering analytical and problem-solving abilities (Damopolii et al., 2019). The task-centered activities provided a structured yet flexible environment for students to apply scientific reasoning, while the inquiry-based questions catalyzed their engagement, directly addressing Pun et al.'s (2022) call for effective questioning in EMI science classrooms.

The more modest, yet significant, gains in SV reveal a more nuanced dynamic. The EfT framework was instrumental in making content accessible, as teachers used purposeful classroom

English to scaffold learning and facilitate discourse. This approach counters the deficit view that EMI inherently hinders learning due to linguistic barriers, supporting instead the argument that young learners can thrive in EMI with appropriate pedagogical support. However, the mixed-methods analysis uncovered a critical distinction: while students' confidence and contextual use of vocabulary in oral discussions improved substantially, their precision and accuracy, particularly in written form, lagged behind. This gap highlights a persistent challenge and responds to calls for more research into vocabulary acquisition in primary EMI contexts (Hong & Basturkmen, 2020), emphasizing that learning is not merely memorization but the active construction of meaning through contextualized use (Henschel et al., 2023).

By integrating these three frameworks, this study directly addresses several gaps in the existing literature. It extends the limited research on applying FPI and EfT in primary EMI settings (Hao & Yamada, 2021) and moves beyond purely quantitative analyses of vocabulary instruction (Venida, 2021) by incorporating qualitative insights into students' perceptions and performance. The findings provide empirical evidence that a thoughtfully designed EMI curriculum can simultaneously support dual-domain learning, enhancing both scientific reasoning and language development to a considerable extent. This research underscores the potential of integrating multiple theoretical perspectives to create robust and effective EMI learning environments.

Theoretical and Contextual Contributions

This study extends EMI research by providing empirical evidence from the under-researched primary education level in Thailand. While much of the existing EMI literature has focused on secondary or higher education contexts, relatively limited research has examined theoretically grounded instructional integration in primary science classrooms. By demonstrating that the combined application of FPI, EfT, and IBL can facilitate both science process skills and science vocabulary development, this study expands EMI research beyond language exposure toward structured pedagogical design.

In the Thai educational context, EMI implementation is often policy-driven and associated with English proficiency enhancement rather than systematic instructional design. The findings suggest that integrating instructional sequencing (FPI), inquiry-based pedagogy (IBL), and teacher language mediation (EfT) can strengthen dual-domain learning outcomes. Although conducted at a single private school, the integrated model offers transferable insights for similar EMI contexts in Southeast Asia, where educators face comparable challenges in balancing content mastery and language development.

Conclusion

In conclusion, this study provides evidence that an EMI pedagogical model integrating FPI, EfT, and IBL can effectively enhance primary school students' science process skills and, to a lesser

extent, their science vocabulary. Quantitative results revealed a statistically significant improvement in both areas, with a more pronounced effect on science process skills. Qualitative data corroborated these findings, showcasing marked gains in students' scientific comprehension, critical thinking, and collaborative engagement. However, the analysis also illuminated a persistent challenge: while students' oral application of scientific vocabulary grew, their written precision and spelling accuracy remained underdeveloped.

Despite these contributions, several limitations must be acknowledged. First, the small sample size and the absence of a control group restrict the generalizability of the findings and limit the ability to attribute outcomes solely to the intervention. Second, the inherent language bias of the EMI context may have hindered students' ability to fully articulate their conceptual knowledge, potentially leading to an underestimation of their true understanding. Finally, the one-month implementation period may have been insufficient for the full consolidation of complex vocabulary and scientific writing skills.

Future research should therefore aim to replicate this study with larger, more diverse samples and include a control group to validate the intervention's effects. Investigating the long-term impacts of such integrated EMI models, as well as incorporating explicit writing instruction, would be valuable avenues for addressing the multifaceted nature of language and content development in young learners.

Recommendations

Future research should address the limitations of this study and build upon its findings through several key avenues. Methodologically, studies should employ larger, more diverse samples across various educational contexts, including public and rural schools, to enhance the generalizability of the results. Longitudinal studies are also warranted to assess the long-term impacts of this integrated EMI model on students' scientific and linguistic development, and to identify the factors that contribute to sustained academic achievement.

Furthermore, comparative research is essential to evaluate the efficacy of this integrated instructional model against traditional EMI approaches that lack explicit theoretical grounding. Such studies would provide clearer evidence of the added value of embedding frameworks like FPI, EfT, and IBL into lesson design.

From a pedagogical standpoint, given the identified gap in vocabulary development, particularly in written form, future investigations should prioritize targeted interventions. Research could focus on strategies to improve spelling, precision, and the contextual application of scientific terminology among young L2 learners in EMI settings. Finally, exploring the integration of other instructional theories and more experiential learning activities, such as hands-on projects and field-based investigations, could offer further insights into how to simultaneously enhance science process skills and vocabulary acquisition in primary EMI classrooms.

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