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Article

EMI Vocabulary Support in High School Mathematics: A Quasi-experimental Study in Taiwan

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Abstract
In response to global competition and Taiwan's 2030 Bilingual Policy, English Medium Instruction (EMI) has started migrating from higher education to secondary education in Taiwan. Research on EMI effectiveness is mostly based in university settings; less is known about the EMI learning outcomes and pedagogies in high school scenarios. The present study compares the learning outcomes of an online EMI and a non-EMI math course in a senior high school through a quasi-experimental design and further examines the support for subject vocabulary on students' learning performance in EMI classes. The initial statistical results show no significant difference between the learning outcomes of the EMI and non-EMI classes. Further examination of the instructional design of the EMI course, together with student feedback, suggests that math vocabulary instruction, including matching games and authentic tasks, positively affects the students' motivation, and engagement. The results indicate that contextualized vocabulary learning benefits both the subject and language learning, including the authentic tasks that allow students to use the vocabulary in context. Pedagogical implications drawn from this study emphasize the importance of vocabulary support for EMI, and recommend integrating vocabulary support as either an integral or extra component in high school EMI curriculum.

Keywords
EMI (English Medium Instruction), secondary education, disciplinary-specific vocabulary, game-based learning, authentic learning

1. Introduction

The acquisition of vocabulary has historically constituted a pivotal facet within the realm of second language acquisition, as it facilitates learners' ability to grasp, communicate, and express themselves through language. Learning second language (L2) vocabulary is a complex and multifaceted process.

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One common misconception is that vocabulary knowledge can be solely measured by the number of words a learner knows. However, effective use of vocabulary is also influenced by the depth of knowledge regarding those words, encompassing their meaning, form, and usage. Vocabulary depth includes a learner's knowledge of various aspects of a word, such as its meaning, pronunciation, grammatical features, and usage in different contexts (Nation, 2013). Utilizing L2 vocabulary knowledge effectively for learning a professional subject is undoubtedly a complex interplay of various factors, and not just solely contributed by vocabulary size alone. Learners need to go beyond mere recognition of words. They should understand the nuances of word meanings, how words are pronounced and written, and how they fit into sentence structures. This comprehensive understanding allows learners to use words appropriately and fluently in real contexts (Schmitt, 2010).

In the context of English medium instruction (EMI), the learning, teaching, and assessment objectives are mainly on the subjects (Airey, 2016). However, it is acknowledged that with more exposure to the medium of instruction, students' English language proficiency might improve as an additional learning outcome (Schleppegrell, 2020); furthermore, the content and the language learning should not be separated as the language, specifically vocabulary, is also part of the disciplinary content knowledge (Schleppegrell & de Oliveira, 2006; Stohler, 2006). In other words, EMI courses aim to enhance content knowledge explicitly and might have implicit language learning objectives.

Therefore, the efficient process of acquiring academic vocabulary could be considered a key to effective learning outcomes (e.g., Uchihara & Harada, 2018). Learning in an L2 is much more challenging than learning in an L1, as the learners face "linguistic and content barriers" (Ma et al., 2022, p. 96). Peng and Xie (2021) have found various issues related to implementing EMI, highlighting listening comprehension and vocabulary knowledge challenges. A notable concern within the ambit of EMI is the fact that learners are typically not afforded specialized, subject-specific vocabulary training prior to their enrollment in EMI courses. This lacuna in preparatory language instruction may, in turn, exert detrimental effects on the overall quality of learning outcomes. Thus, the acquisition and effective utilization of academic vocabulary within the context of EMI necessitate a comprehensive approach that considers the unique challenges and demands imposed by learning in a second language.

While EMI has become the norm predominantly in higher education, research on its impact and effectiveness in secondary education is scarce. EMI in secondary schools could potentially cater for students' future needs both in higher education and at the workplace, and the factors influencing EMI effectiveness in secondary education particularly need more attention (Lin & Morrison, 2010). Therefore, the present study set out to investigate the learning outcomes and pedagogy development of a high-school EMI mathematics course. Specifically, this study proposed and evaluated a pedagogical model of teacher collaboration that facilitates a smooth transition from L1-instruction to EMI. This proposed pedagogical model aims to assist the learners to tackle the double barriers of both the content and the language with satisfactory learning outcomes.

2. Literature Review

2.1 Internationalization and the bilingual policy in Taiwan

Following the trend of the internationalization of universities (Lillis & Curry, 2010), English language has been used as a lingua franca in academic contexts for decades (Ou et al., 2023; Mauranen, 2012). To attract students from around the world and develop global talents, universities are offering EMI courses more than ever (Dearden, 2015; Dafouz & Gary, 2022). The rapid growth of EMI endeavors across the globe is evident, as the number of EMI programs and courses in higher education institutes has increased dramatically particularly in East Asia (e.g., in Japan, South Korea, China, and Taiwan) (Chapple, 2015; Hu & Alsagoff, 2010). As a shared experience in East Asian regions, EMI is not only a pedagogical challenge in classrooms, but has also caused anxiety among parents and students of all ages,

as the linguistic capitals of English nowadays are high, and usually associated with more resources and income, better jobs and education, and higher social and economic status (Silver, 2005). In Taiwan, the government has set a vision of the 2030 Bilingual Policy (National Development Council, 2021), which further increases the cultural symbolic capital of the English language.

The Taiwan 2030 Bilingual Policy aims to accelerate EMI in higher education and schools of all levels, and with such a strong desire to compete globally, educational sectors of higher education have already invested a great amount of effort into this EMI trend (National Development Council, 2021). Yet, no empirical evidence of actual implementations from the field has been systematically and proportionally documented to meet the visions and expectations of EMI. While English proficiency among teachers and students is undoubtedly a crucial aspect, it is not the sole determinant of effectiveness and outcomes. Instead, a broader perspective is necessary to understand the complexity of EMI implementation. Various influencing factors also include the complexity of the subject matter, individual motivation, and previous EMI experience (Huang, 2015; Peng & Xie, 2021). Some subjects may be inherently more challenging to teach or learn in a second language, requiring a higher level of language proficiency, especially vocabulary knowledge, from both teachers and students (Reynolds et al., 2022). For example, teaching and learning advanced mathematics or scientific concepts in English may demand a higher level of vocabulary size and depth (Reynolds et al., 2023).

2.2 Pedagogical approach and Medium of Instruction (MoI) in secondary education

Currently in Taiwanese high schools, the dominant medium of instruction (MoI) is Mandarin Chinese. Given the social and economic capital of the English language, it could be expected that in the near future, high school graduates with an English MoI certificate can be more competitive on the job market or when applying for colleges (Hamid et al., 2013). High schools that offer EMI courses and MoI certificates of English could have become attractive to students and parents in Taiwan. In another Asian context, Evans and Green (2007) found Hong Kong university students had problems with academic vocabulary even though most of them had prior EMI experience in high schools. It was also found that Hong Kong students were insufficient in English speaking to actively participate in EMI class discussions (Evans & Morrison, 2011). The question that remains unknown is whether the high school teachers and students are ready to jump on the EMI wagon.

Whether current Taiwanese high school students are equipped with sufficient language knowledge to study different subject matter in English remains a critical issue to be explored. Regarding English language skills, the comprehension and application of vocabulary, encompassing both academic and technical terminology, hold significant sway over the educational achievements EMI contexts. Vocabulary knowledge plays a pivotal role in shaping the effectiveness of learning outcomes in such settings. It not only facilitates effective communication but also underpins comprehension and competence across diverse academic and specialized subject areas, highlighting its paramount importance in EMI pedagogy (Nation, 2013; Hong & Basturkmen, 2020; Reynolds et al., 2022).

Considering the complexities and nuances of subject-specific vocabulary, it is important to note that students with higher English proficiency or larger vocabulary sizes do not necessarily achieve better learning outcomes in EMI classes (Uchihara & Harada, 2018). Take the word “function” for example; it refers to the concept where each input is paired with exactly one output in mathematics whilst it pertains to the intended purpose of a specific object in general language use. Therefore, specific vocabulary instruction in or before EMI courses on subject-specific English vocabulary could possibly lay a foundation for later successful learning, especially in mathematics and science (Coxhead & Boutorwich, 2018). Therefore, enhancing our comprehension of subject-specific vocabulary and its significance for high school students in EMI environments should constitute a primary focus for EMI researchers and educators of all levels. This imperative task necessitates dedicated attention across the spectrum of educational practitioners, from elementary to higher education. By delving into subject-specific lexicons,

researchers and practitioners can not only enhance the overall efficacy of EMI instruction but also cater to the specific needs and challenges faced by high school learners. This inclusive approach ensures a more comprehensive and tailored EMI experience, ultimately fostering improved learning outcomes.

2.3 Vocabulary instruction for EMI

In Taiwan, English vocabulary is usually taught explicitly in classrooms rather than other implicit methods, such as extensive reading or listening (Tang, 2020). The learners are provided a list of vocabulary and guided to use the target vocabulary for tasks. Explicit instruction allows learners to learn target words in isolated or simplified and context-free settings, in which the learners can understand the meaning and form of the words directly (e.g., Lee, 2003). However, explicit instruction alone may be insufficient to enable learners to apply the vocabulary appropriately in real contexts (Beck et al., 2013; Tang, 2020; Reynolds et al., 2022). Another effective pedagogy of vocabulary learning is through contexts. In the contextual approach, learners can learn new vocabulary by encountering them in context or using them for authentic tasks (Beck et al., 2013). In modern classrooms, authenticity and learning tasks can be supported by multimedia and enhanced by educational games. Chen and Hsu (2020) have found that educational games enhance the knowledge of both the content and vocabulary of the subject. More recently, Soyoof et al. (2022) suggested that the multimodal context of educational games and the repetitive exposure of the target vocabulary positively contribute to the learning gains in both the content and the vocabulary. Learning new vocabulary in context enables learners to understand how words are used in authentic situations to develop a deeper understanding of words' meanings and usages. As learning in English is never learning English, a deep and good understanding of the vocabulary is particularly important for learners in EMI.

As the learning objective of EMI is the subject matter, rather than the language, the EMI teacher might not, cannot, or should not emphasize on the language used, resulting in an overlooked dimension in EMI pedagogies: the linguistic demands, especially vocabulary support (Lo & Fung, 2020; Reynolds et al., 2022). Nonetheless, if the learners are not equipped with the knowledge of the language used in the English instruction, namely the vocabulary, their subsequent learning of the subject would be adversely affected, as faculty from various disciplines have raised similar concerns (Galloway & Ruegg, 2020; Reynolds et al., 2022). Evans and Morrison (2011) found that students in EMI had difficulties understanding subject vocabulary and expressing themselves. Specifically, mathematics vocabulary has long been considered a critical component for mathematical proficiency, as the comprehension of mathematics vocabulary, including numbers, symbols, words, and diagrams, would affect conceptual understanding and complex operations (Riccomoni et al., 2015). Mathematics vocabulary can be taught in various methods, such as explanation, repetition, game-based activities, or collaborative tasks, for both L1 and L2 learners. Powell et al. (2020) further found that learners with limited mathematics vocabulary knowledge would score lower in equation solving than those without word-problem difficulty, indicating L2 learners might need specific and focused instructions on the language of mathematics. A recent meta-analysis (Lin et al., 2021) also suggests mathematics vocabulary to be a strong mediator for mathematics performance, especially for higher-order reasoning.

Beyond the inherent diversity in the subjects taught in EMI, it is essential to recognize that the age groups and educational levels of the students can also significantly influence the outcomes of the learning process. While the primary emphasis of EMI courses is placed on content acquisition and comprehension (Airey, 2016), it is noteworthy that alongside this content-centric approach, there is a consistent and prevalent occurrence of language-related instruction and discussions (Basturkmen & Shackleford, 2015; McLaughlin & Parkinson, 2018). Hong and Basturkmen (2020) identified patterns of language-related episodes (LRE) in high school settings that were similar and had been previously found in higher education settings and found high school teachers tended to be more proactive in highlighting disciplinary-specific language use that than lecturers in universities. This finding raises the possibility

that EMI courses in secondary education may necessitate a greater emphasis on developing disciplinary vocabulary knowledge than their counterparts in higher education. It is possible that EMI in secondary education might require more emphasis on disciplinary vocabulary knowledge than similar courses in higher education.

The majority of the current findings regarding mathematical vocabulary instruction are based on the context of either higher or elementary education settings, while the empirical evidence for such vocabulary training in secondary EMI education is scarce (Hong & Basturkmen, 2020). Similar gaps in discipline-specific vocabulary education have been identified within analogous Asian educational settings, such as Hong Kong (Evans & Green, 2007). In other words, students' knowledge gaps in English mathematics vocabulary might sabotage and impair subject learning (Peng & Lin, 2019). This deficiency underscores a broader issue across the region, where educational programs often neglect the importance of equipping learners with vocabulary tailored to specific academic disciplines (Xiao & Cheung, 2021). Addressing this gap is crucial not only for enhancing language proficiency but also for promoting a deeper understanding of subject matter and improving academic performance within these contexts. It highlights the need for a concerted effort to incorporate discipline-specific vocabulary instruction as an integral component of educational curricula in various Asian settings. In other words, it could be a top priority to provide vocabulary instruction before or along with EMI courses to ensure better learning outcomes, especially for high school students who rarely have prior EMI experiences.

2.4 Learning effectiveness in EMI and non-EMI classes

The learning effectiveness in EMI and non-EMI classes, as revealed in the past studies, is not conclusive. According to a recent review (Aizawa, 2023), it remains uncertain whether the instructional strategy is an influencing factor, or more specifically if the MoI affects academic learning. A few studies reported a statistical difference in learning outcomes between EMI and non-EMI settings (Civan & Coskun, 2016; Peng & Xie, 2021), while other studies found no significant difference (Arroyo-Barrigüete et al., 2022; Dafouz & Camacho-Miñano, 2016). Aizawa (2023) argues that learning effectiveness can be achieved with a combination of effective institutional and academic support; it is also noted that technology integration can potentially play a vital role in enhancing the learning effectiveness in EMI setting (Lee, 2003; Min et al., 2019). Either the online learning activities or the computer-mediated terminology pretraining has been found to enhance learners' performance (e.g. Chen & Hsu, 2020). These findings need to be interpreted with caution as most EMI literature is currently set in the context of higher education, and it remains unclear whether these findings can be applicable to secondary education and learners of different ages and learning needs. The learning effectiveness and outcomes of EMI courses continue to be the point of debate (Peng & Xie, 2021). The integration of specific pedagogical intervention to facilitate learning in L2, such as terminology training, is worthy of further investigation and determines a definitive relationship between instructional methods and academic learning outcomes.

It is recognized that the learning outcome in EMI is affected by various factors, including the subject's complexity, individual motivation, and prior EMI experience, which collectively influence the effectiveness and outcomes of EMI endeavors in educational settings. Recognizing and addressing these factors is essential for designing and implementing successful EMI programs. This current knowledge and empirical evidence are mostly based upon and derived from higher education, which has a distinct nature from its secondary counterparts in many respects (Hong & Basturkmen, 2020; Dafouz & Smit, 2020). In other words, the findings obtained from research set in university EMI contexts simply cannot be applied directly to high school classrooms. It is imperative to fill this void of EMI research in Taiwanese secondary education contexts, bridging L1 instruction to EMI, and ultimately to achieve the goal of a bilingual nation.

2.5 A bridging vocabulary-based instructional model for better EMI

Two research gaps are highlighted above. First, the EMI literature is largely based on university settings, rarely in the high school context (e.g. Hong & Basturkmen, 2020). Second, discipline-specific vocabulary knowledge in EMI is considerably important yet not sufficiently provided to learners in such EMI context in high schools. While literature has shown that learning subject-specific vocabulary can be beneficial for learning, or both the vocabulary and the context learning can be both enhanced, such as healthcare training for university students (Chen & Hsu, 2020; Soyoof et al., 2022; Violato et al., 2023), the cases of high school students learning vocabulary for EMI mathematics education have not been explored extensively. Therefore, a better understanding of subject-specific vocabulary and its role for high school learners in EMI contexts should also be a central task of EMI researchers and practitioners.

Bridging these gaps in the literature is essential to provide comprehensive insights into effective EMI practices for this specific demographic. As such, researchers and practitioners involved in EMI should prioritize the study of subject-specific vocabulary and its implications, acknowledging its centrality in facilitating successful EMI. In response to the needs of EMI and a void of empirical evidence from high school settings, this study was set out to investigate the learning outcomes of high-school math classes in L1 and L2 (EMI), and subsequently examine the instructional model of the EMI class that emphasizing technical vocabulary building and teacher collaboration to have a better understanding of the effective support for EMI learning.

3. Method

To address the questions surrounding the effectiveness of EMI in the context of secondary education in Taiwan, we initiated a study to explore whether the choice of the MoI influences subject learning outcomes. As part of this endeavor, we conducted a quasi-experiment aiming at assessing the math learning achievements in both CMI and EMI classrooms. Then, we thoroughly examined the learning profiles of the participants in the experimental EMI group to identify potential factors that counterbalance the language barrier.

3.1 Participants

A total of 52 students from two classes in the same high school in southern Taiwan participated in the study (see Table 1 for demographic information). The participating students of the EMI and the Chinese as a Medium of Instruction (CMI) groups were recruited by convenience sampling. The aim of the project was to address the bilingual policies and the effectiveness of distant learning. The participating students of both classes received four math sessions a week throughout the twenty weeks of the semester.

All participants had been informed of the instructional procedures. Oral consents were obtained, and the students were informed that the results of the study would not affect their grades in any way and would be used for research purposes only. Also, participants' anonymity has been well protected in the study. As the participating students were told, the data collection and analysis were not linked to any identifiable information. The results of the study would be presented anonymously. Both the participating students and their guardians signed written consents prior to the utilization of their images.

The CMI and EMI classes were taught by the same non-EMI math teacher, utilized the same textbook, and underwent the same summative assessments. The intervention in the EMI courses was one online math session delivered by an experienced EMI teacher. Both classes followed the curriculum guidelines for senior high school mathematics, which included the same Chinese textbook as the instructional material. The content covered included trigonometry, logarithms, and vectors. Both classes had the same onsite CMI math teacher (T1) with 26 years of teaching experience. While both classes had 4 hours of math instruction, EMI class had one out of the four-hour instruction taught in English by

another math teacher (T2). T2 has 16 years of EMI teaching experience. Specifically, the CMI class had all 4 hours of math instruction taught in Chinese onsite; the EMI class had 3 hours of math instruction taught in Chinese onsite plus 1 hour of math instruction taught in English online. The online EMI math session for the EMI class was delivered via Google Meet and Jamboard, which is an interactive whiteboard application. Other interactive applications, Nearpod, Peardeck and Edpuzzle were utilized to facilitate group discussion and promote interaction. The online math session was primarily delivered in English, with occasional translanguaing to Mandarin Chinese for necessary comprehension check (Creese & Blackledge, 2010).

The result of a school-wide math exam served as the response variable for the EMI and the CMI classes. The math exam was developed by all math teachers in the same high school and administered to all students in the same grade before the EMI intervention. The math exam included 3 single-answer questions, 3 multiple-answer questions, and 7 fill-in-the-blank questions. The exam session lasted 70 minutes. As the test items were reviewed and revised by all seven math teachers who are familiar with the national curriculum and various years of teaching experience in public high schools in Taiwan, the content-related validity of the school-wide math test was confirmed collectively. In this math exam, the students in both EMI and CMI classes performed similarly (, see Table 1). Of note is that EMI class performed better in English (Δ=10.78, p=0.03, see Table 1). All participating students (N=52) are in the same grade, between 16-17 years old.

Table 1

Background Information of the EMI and CMI Classes (N=52)

	EMI class	CMI class
Number of students	21	31
	(9 males; 12 females)	(16 males, 15 females)
Hours of EMI math instruction	1 hour/week	0 hour/week
Hours of CMI math instruction	3 hours/week	4 hours/week
Scores of Math exam		
Scores of English exam	70.43	59.65

3.2 Instructional design and procedures

The research design follows the generic ADDIE model (Armstrong et al., 1978; Peterson, 2003) starting from needs analysis (A) of the high school students, design of (D) discipline-specific vocabulary as supporting materials, with continuous feedback from both CMI and EMI teachers (D) and development of collaborative activities that encourage the students to work together, (I) implementation and delivery of instruction online and in face-to-face setting, and evaluation of (E) the learning outcome and student perception. The design and development process are visualized in Figure 1.

The instructional procedures of the EMI class included two phases (see Figure 1). Phase I was the teacher collaboration before and throughout the EMI sessions. Phase II was the actual delivery of EMI sessions, including pre-, mid- and post- language supporting activities for the students. The CMI teacher (T1) was the original math teacher for both classes, and the EMI teacher (T2) was an EMI math teacher from another bilingual school. T1 and T2 collaborated closely throughout the semester, aligning content learning objectives and curriculum and ensuring a smooth transition between onsite and online sessions (Figure 1). The two teachers went through ADDIE weekly. Every week, in initial CMI sessions (Analysis) T2 observed T1's onsite teaching (from video recordings) and familiarized herself with key concepts and the specific vocabulary of the week. T2 then designed weekly lesson plans and vocabulary lists for

T1 to review for the next session (Design). After discussion and revision (Development), T2 delivered the online math session (Implementation) and evaluated student performance in the same session (Evaluation).

To familiarize the students with discipline-specific English vocabulary, T2 employed two extra instructional activities prior to the forma to support learning; one activity was prior to the EMI session, and the other was after each EMI session. The first activity was to provide vocabulary lists on Google Classroom before each online session for self-preview. Alternatively, she would prepare a matching game in which the students have to match the mathematics vocabulary with equivalent English and Mandarin meanings at the beginning of the EMI session (Figure 2). After each EMI session, T2 uploaded a 5-minute video on the Edpuzzle platform summarizing that week's content for the students to review.

Following the contextual approach to vocabulary teaching, T2 integrated common usage of relevant mathematics vocabulary in her delivery to further develop students' discipline-specific vocabulary knowledge, which could potentially enhance their learning of the subject (Evans & Green, 2007; Hong & Basturkmen, 2020). For example, T2 remarked on the terms "determine" and "determined" when teaching the determinant in EMI math sessions. The word "determinant" is a scalar value calculated from a square matrix, while the word "determine" refers to finding a value or making a decision. The word "determined" describes a person who resolves to achieve a goal. T2 incorporated these related terms into EMI math classes and allowed the students to learn the vocabulary in context to foster a deeper understanding of the mathematics concept (Beck et al., 2013)

Figure 1

Bridging Model (smooth transition to EMI)

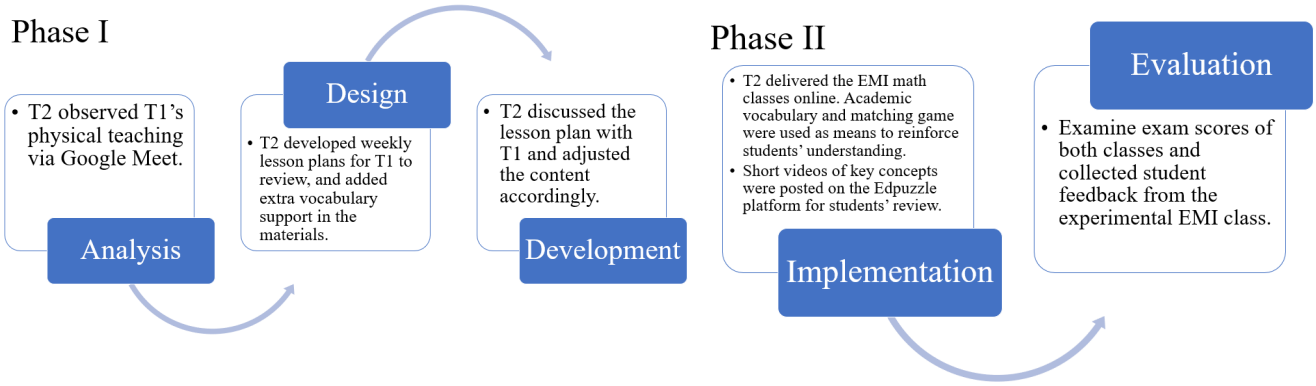

Figure 2

Students in the EMI Class Playing a Word-matching Game Before the EMI Session

Figure 3

Student Posters for the World's Ferris Wheel through Trigonometry Project (ungraded)

In addition to the pre- and post-session activities to support vocabulary learning and ensure comprehension of EMI sessions, T2 assigned an authentic task, *World's Ferris Wheel through Trigonometry*, which allowed the students to apply their knowledge of academic vocabulary about mathematics in the context of real-world objects. The facilitation of this hands-on group project included (1) initial online instruction on using trigonometry to model the height of a Ferris wheel ride, (2) student viewing of two short videos about Ferris wheel in English, (3) student researching the Internet for real Ferris wheels around the world and selecting one as their target, and (4) student oral presenting a famous Ferris wheel and explaining how to use the trigonometric function to model the height of the wheel with posters created by themselves (Figure 3). Discipline-specific vocabulary, such as diameter, period, and amplitude, needed to be used frequently and accurately in the context for communicative purposes throughout the authentic task (Maina, 2004).

3.3 Data collection and analysis

The results of this study are based on both quantitative and qualitative data collected by T1 and T2. Firstly, a quasi-experiment design was chosen to examine that of CMI and EMI classes in the high school setting of the present study, as it has been adopted to compare the learning outcomes of tertiary students (Bowles & Murphy, 2020; Peng & Xie, 2021). The quantitative data accounts for math test scores, independently administered by a third-party teacher. The exams were embedded in the school curriculum, aligned with National Curriculum guidelines and were conducted in the students' first language, Mandarin Chinese. A total of four test scores of both the CMI and EMI classes were collected over the course of six months of EMI intervention.

Secondly, the qualitative data accounts for the EMI students' written feedback on their perception of the EMI instructional activities. The written feedback was part of student learning portfolios documenting their learning progress. In the portfolio, the students were given the opportunity to share their thoughts and reflections on the past six periods of learning experience. Students were encouraged to express themselves openly and freely in Chinese without the fear of unintentionally causing offense with their ideas and had been reassured that their feedback would not affect their grades in any way as the data would be analyzed anonymously. In a grounded theory approach, the analysis of qualitative data involves a systematic and iterative process of labeling, coding, and categorizing to derive meaningful patterns and themes directly from the data (Yin, 2009). The instructor of the EMI class (second author) and the first author conducted the qualitative analysis. We first started with open coding separately. In the

coding process, constant comparison was employed. New data was compared with existing codes and categories to refine and modify the two emerging themes: instructional activity and learning experience. The identification and categorization of the initial open coding reached nearly 99% consistency. We then discussed and negotiated the inconsistent labels and reached consensus. Lastly, we used member checking with the students to confirm our analysis results. The qualitative data from each student was numbered as S-ID, such as S-01, S-02 for data presentation.

4. Results

This study was undertaken to tackle the challenges surrounding the effectiveness of EMI in secondary education within the Taiwanese context. The primary objective was to investigate whether the choice of the MoI influences subject learning outcomes subject-specific learning outcomes. Moreover, if this negative impact is not observed, the study aimed to identify any influential factors that might counteract the potential language barrier posed by EMI, thereby facilitating a smoother transition over the content barrier.

4.1 Learning outcomes of the CMI and EMI math courses

To answer the first research question, we compared the learning outcomes of EMI and CMI classes, controlling the students' initial English proficiency. We conducted ANCOVA to examine whether there exists a difference of learning gains in Mathematics between EMI and CMI. Specifically, we wanted to know if the students with 6 months of EMI perform as well as those in CMI class in the Math subject.

In ANCOVA analysis, English exam scores were controlled as covariant to examine the difference between the 1st and 4th math exam scores (dependent variable), meaning the learning gains in the math subject. The assumptions for ANCOVA were tested. Interaction between covariate and group was not significant (F = 0.878; p =.422), confirming the homogeneity of regression slopes. There was no significant difference in Levene's Test of Equal Error Variances (F = 0.051; p =.822).

As reported in Table 1, EMI students performed slightly better in an initial English exam than CMI students. The mean score gain of the EMI class is 14.38 and that of CMI class is 10.87 respectively. On average, EMI students performed better than CMI students in test scores but no statistical difference was found between the learning gains in Math when English proficiency were controlled (adjusted , adjusted , p =.22), as Table 2 shows.

Table 2
ANCOVA Analysis of Controlled Learning Gains of CMI and EMI Classes

	Type III sum of squares	df	MS	F	p
English proficiency (covariant)	248.00	1	248.00	1.42	.24
Class	276.02	1	276.02	1.58	.22
Residuals	8556.43	49	174.62		

Test scores show one aspect of the students' learning outcomes and cannot comprehensively represent their overall performance. In the context of the test-oriented Taiwanese high school system, test scores nonetheless serve as one crucial indicator of the students' academic achievement, and the students are strongly motivated to achieve high scores. The result of the ANCOVA analysis shows that the MoI, Mandarin Chinese (L1) and English (L2) of the two classes had no significant effect on their learning outcomes. In other words, students in the EMI class learned no worse than those in the CMI class.

4.2 Student perception of mathematics vocabulary training

The result of the initial ANCOVA analysis led to our second research question. When the MoI is not an influencing factor of learning gains, we wanted to further explore the learning experience of EMI class. To more comprehensively investigate other factors in the context and to address the second research question, we conducted a detailed analysis of students' post-course written feedback. We began by immersing ourselves in the written feedback to generate initial codes. We then compared our initial codes with each other and reached a consensus on the coding scheme through negotiation and discussion. The further investigation was set out to provide a holistic view of the learning context by considering the students' perspectives. In post-course written feedback, none of the students in the EMI class indicated that academic vocabulary constituted an obstacle to their learning. This result, although initially surprising, makes sense. One student in the EMI class reported that vocabulary training helped her grasp many mathematical concepts, enhancing her overall learning. This, along with other positive feedback, reaffirms the significance of mathematics vocabulary training.

4.3 Student perceptions of instructional activities and learning experience

The qualitative data from the student written feedback highlights two themes: students' favor of the interactive activities and their positive learning experience in EMI setting. The findings suggest that the students perceived the overall instructional activities well and were in favor of the interactive games of the EMI sessions. The interactive and game-like features of the learning tasks had been mentioned and praised repeatedly in the student feedback. When reflecting on the EMI math classes, the students described the learning activities as "fresh," "fun," "special," and "interesting." One student reported, "(t)he interactive games and rewards offered in this course help me understand the content and gain interest. Among the 21 students in the EMI session, 15 of them reported that they had benefited greatly from the interactive matching games before each session. Instead of just a list of Chinese translations of the English mathematics vocabulary, the interactive and fun nature of the activity was motivational and somewhat eased their anxiety for the upcoming English-medium classes (S-03, S-05). The students highlighted the authenticity of the hands-on project, allowing them to use English math terms in a real context. Overall, the students perceived the project as "engaging and motivating" (S-04).

Regarding the overall EMI learning experience, the students' perceptions were positive, highlighting the review videos and vocabulary training. generally described the EMI classes as challenging, regarding, beneficial, and they looked forward to more of these (EMI classes). One student suggested that the online instructional videos after class can "compensate for the shortcomings of having only one English-taught lesson per week" (S-05). The students expressed a positive perception of both the prep game and the review video, as both were beneficial for the subject learning in English. Another student highlighted the vocabulary support, and the authentic task helped her to connect and combine the subject and the vocabulary, stating "I didn't find it challenging. Instead, it helps to review as I realize that many academic English words are closely related to everyday English. As I attended more classes, I gradually became aware of the various ways express mathematical concepts" (S-03). Other than the subject learning, one student reported that "learning math in a different language is like learning math from a whole new perspective." Most students expressed compliments, reporting that the EMI "exceeded their expectation" (S-15). Also, our data show that the students perceived a language gain, as one of the students in the EMI class wrote "(t)he benefits gained in this course are not only general mathematical knowledge but also the digital skills, as well as practical experience in applying English" (S-12).

5. Discussion

This study was designed to explore the interplay between language as a MoI and the attainment of subject knowledge. Specifically, it sought to discern whether the MoI, in this case, English, acted as an

impediment to effective learning or if other factors mitigated its potential hindrance, allowing students to overcome language-related barriers and achieve positive learning outcomes in their subjects. By addressing these questions, the study aimed to provide valuable insights into how EMI can be optimized for secondary education in Taiwan, ultimately contributing to the enhancement of educational practices and outcomes in this context.

Our initial statistical analysis shows no significant difference between CMI and EMI classes in the Math learning. Given the students' English proficiency in both classes was controlled, this result suggests that the foreign language barrier alleged in EMI literature seems to have no negative impact on the students' math learning outcomes. While the majority of current EMI literature considers the MoI, English, would increase learning difficulty for the students (e.g., Peng & Xie, 2021), the language barrier might be alleviated by extra language support or instructional activities. Studies in favor of EMI claimed EMI hardly affects single subject learning (Dafouz & Camacho-Miñano, 2016) and long-term academic performance across subjects (Arroyo-Barrigüete et al., 2022). It seems that the alleged language barriers in EMI could be compensated or mitigated by other personal or instructional factors. In this study, our results suggest that students in the EMI class could learn just as well as those in the CMI class, potentially due to the interactive pedagogy in the EMI class.

The personal and instructional factors that possibly mitigate the EMI barrier include student motivation, attitude towards EMI, and pedagogical approaches (e.g., Li & Wu, 2018). As the literature has suggested, EMI effectiveness can be increased by proper academic support (Aizawa, 2023; Peng & Xie, 2021). Yet, the specific types of instructional support that can improve EMI learning outcomes remain uncertain. With this uncertainty in mind, we further investigated the learning profiles and feedback of the students in the EMI group and found students' overwhelmingly positive perceptions of the educational games and authentic tasks, as reported by Beck et al. (2013). Qualitative evidence from the written feedback covers two main themes: interactive activities and positive learning experience. The interactive activities in EMI class include the vocabulary matching games, and students reported it was a fun way to learn discipline-specific vocabulary. This educational matching game is fun in nature and help to build math vocabulary foundation, decreasing the cognitive load and learning difficulties of the subsequent EMI math session. Such vocabulary training or instruction should provide repetitive exposure of the subject vocabulary and allow the students to use the target vocabulary in context (Hong & Basturkmen, 2020). According to student feedback, another helpful support for EMI was the review video after each EMI session, enhancing both the content and the language aspects. In the videos, the students could listen and watch how the language, especially the math vocabulary was used in the context, multiple times. For the students with lower English proficiency, the videos were the opportunity to review, study, and clarify unclear concepts; students with heightened interest and motivation were willing to put more effort into learning (Guo et al., 2022). Similar findings on technology integration in EMI have been reported but in higher education settings (Lee, 2003; Min et al., 2019).

Vocabulary knowledge, especially discipline-specific and academic vocabulary knowledge, is a crucial factor influencing the learning outcomes in EMI (Beck et al., 2013; Galloway & Ruegg, 2020; Hong & Basturkmen, 2020), and has been reported in a similar Asian context (Evans & Green, 2007; Hong & Basturkmen, 2020). In the present study, it is surprising that none of the EMI students reported difficulties in vocabulary, as previous findings had suggested (Beck et al., 2013; Evans & Green, 2007). With further investigation of the student feedback, it is noted that the teaching of math terms before the EMI class possibly counterbalanced the difficulty of the content. As suggested by Riccomoni et al. (2015), mathematics vocabulary should be taught at the beginning through explanation, allowing the students to connect the meaning and the language; throughout the course, the students can be provided with opportunities to exercise their understanding and apply the language through cooperative tasks to maximize learning outcomes. Reynolds and Ding (2022) reported that learners were able to incidentally acquire vocabulary from working on a task even when the task did not specifically aim at learning vocabulary. Similarly, Soyoof et al. (2022) and Dang et al. (2022) both suggest that vocabulary repetition could lead to the incidental acquisition of the words. According to these findings, the tasks in

EMI settings could be designed to achieve content learning while requiring frequent use of disciplinary vocabulary (Schleppegrell, 2020) so that learners would be more likely to acquire the language as additional learning gains in addition to subject learning.

The online matching game facilitated prior to the EMI class in this study is found to have a positive impact on student perceptions and the potential of their learning as well. The benefits of early instruction of math vocabulary seem obvious as it could promote understanding of the following EMI class and familiarize the students with the language and terms that are necessary for further concepts and more complex tasks. The matching game provides repetitive exposure of mathematic vocabulary (Dang et al., 2022; Soyoof et al., 2022) and equips the students with higher fluency of terminology and potentially the concepts associated with them. Furthermore, it has been observed that the students in the present study interacted more with others in the collaborative project with the newly learned subject-specific vocabulary, constituting language-related episodes. This is crucial because such interactions not only facilitate the practical application of vocabulary in relevant contexts but also contribute to deeper language acquisition and retention (e.g. Fernández Dobao, 2014). This finding suggests that language proficiency is not only acknowledged but also actively integrated into the overall learning experience, implying that content learning and language learning can be enhanced simultaneously (Hong & Basturkmen, 2020).

As stated by Uchihara and Harada (2018), effective acquisition of academic vocabulary is considered crucial for achieving a positive learning outcome through EMI. In the EMI class, T2 initiated the course by explaining academic vocabulary from the slides, followed by a content introduction. As such, the timing of vocabulary instruction might be crucial and should be prior to or in the early stage of the content instruction. The slides included a variety of English materials for students to use as a reference after the lesson. The specific vocabulary instruction provided within or before the class contributes to enhancing students' learning performance (Coxhead & Boutorwich, 2018; Lee, 2003; Reynolds & Ding, 2022).

Furthermore, group projects combined with presentations engaged students in discussing the learned concepts. In order to complete the project, a group of 4 to 5 individuals must connect the math concept with real-life examples and showcase their understanding by utilizing English to structure their thoughts. The project, which involved presentation in English, resembled project-based learning and contributed greatly to the enhancement of students' oral communication proficiency. Our qualitative data also reveals that students perceive themselves as having experienced stronger motivation and engagement in the hands-on project. The benefits of collaboration among students, including greater academic achievement and critical thinking, are well documented in literature, and should also be included in EMI settings (Gokhale, 1995; O'Donnell & Hmelo-Silver, 2013).

Based on the findings of the present study, we tentatively claim that EMI is not primarily centered around the English language itself, but rather focuses on pedagogy and providing diverse support to help students manage potential language barriers in the EMI class of this study. As observed, the foreign language in EMI practice is not necessarily a barrier but potentially benefited both the content and language learning (Aizawa, 2023; Stohler, 2006). As we have found that effective EMI delivery, together with students' academic vocabulary knowledge (Hong & Basturkmen, 2020), could mitigate the potential negative learning impact instead of causing the alleged learning loss in an L2 environment (Civan & Coskun, 2016; Peng & Xie, 2021). In our pedagogical intervention, we incorporated interactive activities and vocabulary support, and these integrations of interaction and collaboration seem to successfully increase motivation, engagement, and academic achievement. Specifically, the multimodal and self-paced technology integration (Lee, 2003), the initial matching game (Soyoof et al., 2022) as early vocabulary instruction, and an opportunity to apply and use the new knowledge and language (Reynolds et al., 2022; Tang, 2020) together could potentially contribute to the successful learning outcomes of this high-school EMI math class.

As recognized in the literature, the applicability of research findings derived from university English as an EMI setting cannot be straightforwardly extended to the high school classroom environment.

Consequently, a pressing need for comprehensive EMI research within the framework of Taiwanese secondary education is obvious. The findings of this present study can be one step to establishing a seamless transition from native language (L1) instruction to EMI, aligning with the broader objective of achieving the Taiwan 2030 Bilingual Policy. Specifically, the quantitative and qualitative findings of the present study together suggest (1) EMI math education could achieve the same learning outcomes with sufficient (2) mathematics vocabulary instruction that are (3) interactive, authentic, and contextualized. Effective EMI in secondary education should include pre-sessional game-like vocabulary training to improve later learning outcomes (Chen & Hsu, 2020), and EMI instructors are suggested to employ online tools to adequately engage and support student learning in the L2 environment.

6. Pedagogical implications

Our findings, along with the proven pedagogical model, can provide additional insight into the practicability of EMI courses in secondary education, which can help the shift from CMI to EMI as a connecting cornerstone of bilingual secondary and tertiary education in Taiwan. This quasi-experimental EMI intervention involved co-teaching and relevant support, including subject-specific vocabulary game-like training and multimodal collaborative and authentic tasks. The pedagogical values inherent in this model are threefold: (1) contextualized vocabulary learning through engaging games that help the students grasp essential terms in a meaningful context; (2) content and language integration that enhance the learning of both the subject and the language skills, and (3) authentic tasks that promote deeper understanding and application of knowledge and an opportunity to use the target language, increasing their confidence in using English for further academic pursue. In addition to these pedagogical benefits, this co-teaching model is flexible, as the vocabulary training component can be an extra add-on for those in need or an integral part of an existing EMI class. It is hoped that this model could facilitate better learning and a smooth transition to college EMI for high school students in Taiwan.

The key pedagogical implication derived from these findings underscores the importance of incorporating game-like vocabulary training into the educational framework. This approach should be designed to offer students repeated exposure to subject-specific vocabulary while enabling them to apply this newly acquired lexicon within meaningful contexts. This strategic emphasis on subject vocabulary is poised to have a profoundly positive impact on subsequent learning experiences within the EMI environment. Such specific instruction on subject vocabulary can positively facilitate later successful learning in the EMI context. While EMI targets at subject and content learning, the language barrier or language-related issues cannot be ignored. Attention and extra vocabulary support can be the key to satisfactory learning outcomes, especially for high school students, as these early exposures to academic and subject-specific vocabulary in secondary school can better prepare students for English-medium higher education and facilitate a smoother transition into a fully immersive EMI setting less challenging. Integrating game-like vocabulary training within the pedagogical framework can serve as a vital steppingstone toward achieving the overarching educational objectives.

7. Conclusion

A reconsideration of EMI curricula in secondary education is needed. With a more robust integration of disciplinary vocabulary instruction, educators can better prepare students to navigate the nuanced linguistic landscape of their chosen fields, ultimately fostering more effective learning outcomes within EMI programs at the high school level. It is acknowledged that the complexity of EMI implementation in secondary education in Taiwan extends well beyond quality teaching and English delivery. Addressing these multifaceted challenges comprehensively might not be achievable in a single study. Nevertheless, it is crucial to promptly direct attention toward relatively specific aspects of these broad issues and begin to better understand and work collaboratively toward a mutual and shared bi- and/or multi- lingual nation.

As the importance of EMI in secondary and primary education is increasing, an effective pedagogical model that can be facilitated in the current context of Taiwanese high schools is imperative.

The present study possesses certain limitations. Initially, it is important to acknowledge that test scores only capture a singular facet of students' learning outcomes and cannot offer a comprehensive portrayal of their overall achievements. Exploring other variables, such as class engagement and critical thinking holds merit. Secondly, our research design included only one hour of math instruction per week taught in English, which might be insufficient to fully examine differences between the EMI and CMI classes' final math scores. Therefore, it is advisable to extend the timeframe for a more accurate evaluation of the learning outcomes with different MoI. Also, given the quasi-experimental design, there could be other factors that were not controlled in the present ANCOVA analysis. Conducting the study in a randomized experiment design might have yielded a different statistical result. Lastly, the teaching mode may also impact learning outcomes. Ideally, maintaining consistency in the teaching approach, meaning having both groups taught either face-to-face or online, would help mitigate the potential confounding variables.

Regardless of its limitations, the present study is one of the first investigations into the effectiveness of an online bilingual math course in Taiwan. From a practical perspective, our vocabulary-based instructional model for EMI can be a timely solution to gradually transform CMI into EMI. With collaboration between CMI and EMI teachers, students could learn and study in both languages simultaneously for a given time and with various degrees depending on the students' adaptability. This bridging instructional model for EMI could also potentially alleviate the present shortage of EMI high school teachers, as they could deliver part of the course and collaborate with original CMI teachers. It is hoped that the E in EMI can stand for not just English but also engagement, encouragement, and empowerment through effective pedagogies. It is also hoped that the findings from the present study can help stakeholders to make better decisions in the design of EMI curriculum and teaching practices and could further raise theoretical issues, generate questions, and identify other problems in EMI contexts.

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