Teaching Thai University Students How to Write Research Abstracts and Research Reports: The Case for Science Using CLIL[1,2]

Attapol Khamkhien[3], *Thammasat University, Pathumthani, Thailand*
Budsaba Kanoksilapatham[4], *Silpakorn University, Petchaburi, Thailand &*
Academy of Arts, Royal Society of Thailand

Abstract

This study examines the effectiveness of Content and Language Integrated Learning (CLIL) implementation in science subjects and reports on the challenges that content teachers encountered during CLIL instruction. In addition, the study attempts to investigate students' perceived knowledge of and satisfaction towards the implementation of CLIL. To accomplish these goals, relevant CLIL instructional materials were developed by the researchers and subject content teachers. Content teachers received training in English to apply the designed material and implement the CLIL instruction prior to CLIL classes. A convenience sample of 24 university students participated in this study. They were required to write research abstracts and reports in English according to the knowledge of genre and move-based structure. The data collection was conducted using a mixed qualitative and quantitative method. Student abstracts written in English were also analysed qualitatively to investigate the use of linguistic features, structural elements, and vocabulary. Additionally, six subject content teachers and six students were interviewed about their perceptions of and challenges from CLIL implementation. Student questionnaires about their attitudes towards CLIL implementation were then used to collect quantitative data. Over the seven weeks of CLIL lessons, the interview results revealed that close collaboration between content and language teachers prior to CLIL implementation was necessary to affirm the steps and procedures to be applied in the classroom. Some of the content teachers conveyed the importance of advancing students' language-related knowledge in expressing scientific ideas in English. Most students also expressed their satisfaction towards CLIL instruction as it facilitates the learning process, helping them improve their writing and reading skills as well as their ability to use academic vocabulary. The findings of this study advance our understanding of how to implement CLIL lessons, including the importance of CLIL-related training, creating instructional materials, and language integration of content and language learning in science at the university level.

Resumen

Este estudio examina la efectividad de la implementación del Aprendizaje Integrado de Contenido y Lenguaje (CLIL) en materias de ciencias e informa sobre los desafíos que encontraron los profesores de contenido durante la instrucción CLIL. Además, el estudio intenta investigar el conocimiento percibido y la satisfacción de los estudiantes hacia la implementación de CLIL. Para lograr estos objetivos, los investigadores y los profesores de contenidos de la materia desarrollaron materiales didácticos CLIL relevantes. Los maestros de contenido recibieron capacitación en inglés para aplicar el material diseñado e implementar la instrucción CLIL antes de las clases CLIL. En este estudio participó una muestra por conveniencia de 24 estudiantes universitarios. Se les pidió que escribieran resúmenes e informes de investigación en inglés de acuerdo con el conocimiento del género y la estructura basada en el movimiento. La recolección de datos se realizó mediante un método mixto cualitativo y cuantitativo. También se analizaron cualitativamente los resúmenes de los estudiantes escritos en inglés para investigar el uso de características lingüísticas, elementos estructurales y vocabulario. Además, se entrevistó a seis profesores de materias y a seis estudiantes sobre sus percepciones y desafíos ante la implementación AICLE. Luego se utilizaron cuestionarios de estudiantes sobre sus actitudes hacia la implementación AICLE para recopilar datos cuantitativos. Durante las siete semanas de lecciones CLIL, los resultados de la entrevista revelaron que era necesaria una estrecha colaboración entre los profesores de contenido y de lengua antes de la implementación CLIL para afirmar los pasos y procedimientos que se aplicarían en el aula. Algunos de los profesores de contenido transmitieron la importancia de mejorar el conocimiento relacionado con el lenguaje de los estudiantes al expresar ideas científicas en inglés. La mayoría de los estudiantes también expresaron su satisfacción con la instrucción CLIL, ya que facilita el proceso de aprendizaje, ayudándolos a mejorar sus habilidades de escritura y lectura, así como su capacidad para utilizar el vocabulario académico. Los hallazgos de este estudio mejoran nuestra comprensión sobre cómo implementar lecciones CLIL, incluida la importancia de la capacitación relacionada con CLIL, la creación de materiales educativos y la integración lingüística del contenido y el aprendizaje de idiomas en ciencias a nivel universitario.

Introduction

Content and Language Integrated Learning (CLIL) is viewed as an innovative educational approach in which academic subjects are taught in an additional language at any levels of education (Lasagabaster & Sierra,

[1] The earlier version of this paper, which was entitled "A look at content and language integration learning: Students' attitudes, teachers' perceptions and challenges", Proceedings of the International Conference on Applied Research in Education. Diamond Scientific Publishing. https://www.doi.org/10.33422/areconf.2019.07.352

[2] This is a refereed article. Received: 7 March, 2022. Accepted: 14 October, 2022. Published: 4 December, 2023.

[3] attapol.k@litu.tu.ac.th, 0000-0002-6173-8143, Correspondent
[4] kanoksib@hotmail.com, 0000-0002-9796-0002

2010). This widespread method for learning languages empowers learners to acquire content together with a language (Coyle & Meyer, 2020; Díaz Pérez et al., 2018). In formal education, the integration of language learning with specific content has received great interest from European countries and other parts of the world (Banegas, 2011; Coyle et al., 2010). According to the European Commission (2003), CLIL has had a significant impact on the European Union's objective of developing multilingual citizens, specifically because it combines the understanding both of a subject matter with another language. Taken together, this approach can facilitate students' learning while providing them opportunities to explore topics in addition to the necessary learning processes in the desired teaching context (Hall & Townsend, 2019).

The number of English language users worldwide has steadily increased due to the common use of the language for exchanging information in almost every channel of communication. As such, it is essential to be a fluent English speaker in our increasingly competitive world. The growth of English speakers in this globalized world has contributed to considerable changes in teaching and learning in non-Anglophone countries, for instance, encouraging the use of new teaching approaches such as Communicative Language Teaching (CLT), using English as a medium of instruction, promoting bilingual education, etc. to enhance students' English skills. Thailand is not an exception regarding these changes. In this respect, Graddol (2006) suggested that students in higher education should not only be proficient in English for communication purposes, but also study their subjects in this language. However, this argument is quite critical as it has been specifically a dominant one in contexts where subjects are taught in English as a medium of instruction.

In response to the increasing number of English users around the world and various educational changes, English language teachers and professionals have changed their views on how the English language should be taught. For example, some maintain that linguistic development, intercultural awareness and critical thinking skills should be prioritized in teaching and learning a language (Martínez Agudo, 2019). Consequently, English has been used to teach content in both primary and secondary education in such areas as science, mathematics, art, social studies, and even engineering. Several scholars (e.g., Coyle et al., 2010; Hall & Townsend, 2019; Morton & Llinares, 2017) have even turned English teaching into a context-sensitive pedagogy and integrated approach. Consequently, this approach is not only about practicing a contextualized teaching process that suits a particular context, but also about formulating appropriate approaches through the integration of language and content in order to overcome certain obstacles in achieving the desired goals.

Given the main principles of CLIL, with its balance of content and language, CLIL instruction aims to promote learning from both linguistic, content, and cultural perspectives, referring to any type of pedagogical approach for the integration of teaching and learning content and second/foreign languages (Dalton-Puffer et al., 2014; Llinares, 2015). In CLIL classrooms, students are provided with the opportunity to be exposed to authentic materials and learning settings focused on the language teaching and academic subjects (e.g., science, geography, mathematics). It is believed that this integrative approach can help raise students' awareness and their motivation levels by involving them in the language learning process (Lasagabaster, 2019; Mehisto et al., 2008). Based on SLA (Second Language Acquisition) perspectives, students can additionally produce meaningful communication for input and output through the provision of context with task-based, experiential, and problem-based activities in CLIL classrooms (Mackey, 2012; Morton & Llinares, 2017).

English has become the world's predominant language of instruction in academia, especially in tertiary education, since it is widely held that university students should be able to effectively communicate in English after graduation. At most universities in Thailand, it is compulsory for science students to conduct a scientific study or experiment and document their findings in a research paper or at least a research abstract in English. However, most students find the writing process difficult and challenging since there are no academic writing courses in English with explicit instructions or systematic lessons that emphasize composition of scientific research and abstract writing. Moreover, writing research reports and research abstracts has its own academic style and genre covering different rhetorical structures, elements, vocabulary, and linguistic devices for meaningful expression. In this regard, Swales' (2004) genre analysis was relevant as writing research articles and research abstracts must follow a typical organisational structure, consisting of moves and steps characterised by a number of co-occurring linguistic features. At this juncture, it can be said that writing basically requires a range of language skills. Thus, academic writing courses and instruction are exceedingly necessary in this context.

Where the demand for English-language proficiency in both academic and professional fields is concerned, implementation of CLIL in the Thai context is particularly important as it aims at developing the four metalinguistic skills and raising learners' learning motivation to participate in interactive activities. As such, since it is documented that the power and purpose of CLIL instruction aims to improve core language skills like listening, speaking, reading, and writing, research on CLIL outcomes for a single language skill is rarely found, particularly writing (e.g., Lee, 2020; Ying, 2022). Given the effectiveness of CLIL instruction described in previous studies (Lee, 2020; McDougald, 2015; Pérez Cañado, 2018; Sylvén & Thompson, 2015), the present study seeks to examine the challenges associated with providing CLIL instruction to science students in the tertiary educational setting. More specifically, it aims to determine the benefits of CLIL instruction in developing English writing skills amongst Thai undergraduate students studying in the field of science and to investigate the implementation of CLIL in science courses.

Therefore, this study addresses three research questions as follows:

1) To what extent does CLIL instruction enhance communicative competence, especially the English writing skills of Thai undergraduate students in the field of science?

2) What challenges do content teachers encounter when delivering CLIL instruction to such students?

3) What are students' perceived knowledge of and satisfaction towards CLIL instruction?

Literature Review

Content and Language Integrated Learning (CLIL)

CLIL can be described as a "dual-focused approach" that gives equal attention to language and content (e.g., Mehisto et al., 2008, p. 9). According to Morton and Llinares (2017), the CLIL approach places an emphasis on several important aspects of classroom instruction and student development. These aspects include learning processes and cognition, building a safe and stimulating learning environment, using authentic materials, enhancing collaboration between student and teacher, and promoting active learning and scaffolding to encourage autonomous learning. Even in the European context (Fernández Fontecha, 2010; Papadopoulos & Griva, 2014), CLIL is used to teach content through the medium of a foreign language, usually English, although not exclusively, in an integrated manner (Coyle et al., 2010; Coyle & Meyer, 2020).

In most European countries, CLIL is a growing phenomenon as it has been introduced to and implemented with all learners at every educational level by integrating L2 learning and curriculum content, regardless of their L2 proficiency (Coyle et al., 2010). Several scholars (e.g., Griva et al., 2015; Griva & Kasvikis, 2015) point out that the CLIL approach is holistic language learning as students learn and use the language and content knowledge in various subjects. It can improve students' self-confidence and cognitive skills. Sudhoff (2010) proposed that the integrative nature of CLIL lends itself to the adoption of "not only a dual-focused but a triple-focused approach consisting of simultaneously combining foreign language learning with subject content and intercultural learning" (p. 36). Therefore, with successful CLIL implementation, students can learn the language and subject content while improving their linguistic competence and communication skills. The integration of content and language teaching facilitates not only the linguistic acquisition, but also results in cognitive and motivational development (Coyle et al., 2008, 2010; Lasagabaster, 2019).

To effectively integrate learning content and language, Coyle et al. (2010) recommended the basic concept of CLIL instruction consisting of four interrelated principles that underpin effective classroom practices. The focal point here is the interaction between learning (through content and cognition) and language acquisition (through communication and culture), which is so-called 4Cs-Framework.

In response to Coyle et al. (2010), Meyer (2010) argued that the 4Cs-Framework is effective when all C's are incorporated into the process of lesson planning and material development, which unfortunately is very difficult to achieve in a single lesson (Meyer, 2010). Meyer, therefore, developed the CLIL pyramid model (Figure 1), which consists of six dimensions of teaching and learning: a) multifocal lesson planning, b) higher-order thinking skills, c) scaffolding skills and techniques, d) multi-modal input that caters to individual learning styles and accommodates multiple intelligences, e) modes of interaction flexibility, and f) intercultural communication (Griva et al., 2015; Mehisto et al., 2008).

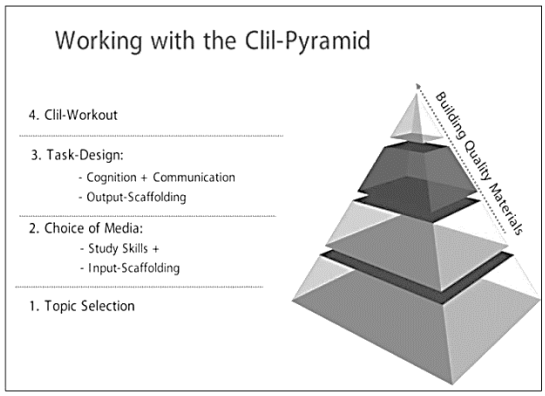


Figure 1: Meyer's CLIL pyramid (Meyer, 2010, p. 24)

As shown in Figure 1, Meyer (2010) suggests that input in the CLIL learning process must be authentic, meaningful, and challenging in order to achieve the 4Cs framework. The materials and topics presented must engage students and allow them to make connections between the new information and their previous experiences. They can also be presented visually to enhance students' understanding and clarify complex concepts presented in a foreign language. In addition, scaffolding is an essential component of effective learning in general. Mayer explains that students need scaffolding to work with the transfer of information and assimilate it through various methods. Students are able to successfully complete a given task when they are provided with the necessary support and structure. It also supports their language development by equipping them with the necessary phrases and subject-specific vocabulary to articulate their ideas accurately. This pyramid shows a systematic, tried, and tested sequence that CLIL teachers can follow and apply to lesson planning and materials (Meyer, 2010). It begins with topic selection and culminates with a review of key content and language components, also known as the "CLIL-Workout". In this regard, in the implementation of CLIL, some of the pertinent questions that have arisen here, including (1) *"Who produces materials for teaching and learning?"*, (2) *"Who sequences lessons?"*, and (3) *"Who prompts the revision of key contents and language components?"* These questions should be considered.

CLIL's Advantages and Its Challenges

Considerable positive impacts on language learning and knowledge acquisition, such as learning motivation, linguistic performance, and thinking skills, have been reported and documented across several academic disciplines (e.g., De Graaff et al., 2007; Lasagabaster, 2008, 2019; Martínez Agudo, 2019; Spratt, 2012; Troncale, 2002). As a new conception of communicative language teaching, CLIL brings together content teachers and language teachers to collaborate on joint curricular systems, exchange ideas, and provide support for classroom activities (Nhan, 2013). Student participation in CLIL classes appears to improve content knowledge because of their exposure to learning opportunities in an interactive learning environment (Morton & Llinares, 2017; Spratt, 2012). In addition, they can have opportunities to share information and communicate with their peers by using a foreign language. In this regard, while organising the interface between language and content-knowledge education, learners should be exposed to the so-called "language triptych" as suggested by Coyle et al. (2010), including a) *language of learning* (learning subject-specific terminology), b) *language for learning* (language structures and speech acts required for successful completion of tasks), and c) *language through learning* (emergent language demands needed by learners during the learning process).

In terms of learning motivation, students who study with a CLIL approach are more likely to increase their involvement and demonstrate a higher motivation level (Fuchs, 2015), in particular, their willingness to be engaged in the instruction process (Lasagabaster, 2011). Moreover, given CLIL's role in improving intercultural competence, introducing CLIL raises students' cultural awareness (Anagnostou et al., 2016; Logioio, 2010) as they acquire cultural elements and thus "build intercultural knowledge and understanding" (Gimeno et al., 2013, p. 5) through culture-based learning projects and topics.

In the learning process, students' cognitive and metacognitive skills can be developed and enhanced as they engage in cognitively demanding academic activities that integrate both content and language (Spratt, 2012). Therefore, the language used should be from the subject content to ensure that language learning involves content-specific discourse and language for the successful completion of tasks (Spratt, 2012), while taking into account the importance of language interaction in the CLIL classroom (Llinares et al., 2012).

According to Sylvén (2013) and Dalton-Puffer's (2011) works, students tend to have more confidence in their language abilities than their non-CLIL counterparts. Additionally, they seem to be proficient in the target language and more willing to take risks in learning a new language. For that reason, useful materials with efficient content should be provided to students so that learning can take place in a classroom with a clear goal for language use. Students need to understand the material and use it effectively to complete classroom tasks using the language effectively. Students should be exposed to the language so that they can use it frequently and extensively, perhaps in more complicated ways, and digest a greater amount of information that successively improves their comprehension skills (Anagnostou et al., 2016; Papadopoulos & Griva, 2014).

Despite its effectiveness in integrating content and language in classrooms, CLIL has been criticised for many difficulties with its application in different contexts. Some scholars (e.g., Butler, 2005; McDougald, 2015) have highlighted the challenges associated with CLIL instruction such as the materials and training required for CLIL teachers. Stathopoulou (2015) emphasised the significance of a balanced combination of L1 and L2 use in CLIL instruction. Particularly, in a multilingual setting, students need to realise intercultural experiences and be aware of applicable language variations in order to participate in such contexts and communicate effectively. This element cannot necessarily be controlled in CLIL settings. Coyle (2008) contends that there is an ongoing debate about whether content experts or language experts should provide CLIL instruction and Dalton-Puffer (2011) claimed that subject-learning matters can be reduced as the instruction should also focus on language. In addition, teachers' experiences are essential for motivating learners to develop self-efficacy, which is the belief that one is able to achieve set goals. According to Mehisto et al. (2008), CLIL classes taught only by content teachers may need second language support, especially in the form of translation. This supports the argument that teachers perceive themselves as either content teachers or language teachers, which in turn leads to a lack of cooperation or the full integration of the different components. This reluctance was evident in teachers' unwillingness to incorporate materials derived from content or language lessons (Coyle et al., 2010; Mehisto et al., 2008; Yassin et al., 2010). Marsh (2008) maintained that the impact of the CLIL implementation may not be appreciated for two apparent reasons: the average level of content and/or language skills of lecturers and students was the same and lectures' engagement was insufficient.

Since the CLIL approach requires teachers with both subject and language knowledge, insufficient understanding of content through the medium of a foreign language is another critical issue for its implementation. Spratt (2012) advocates language training for CLIL teachers as part of their professional development. Johnstone (2000) suggested that CLIL instruction can lead to considerable hesitation and uncertainty on the part of teachers and Escobar Urmeneta (2019) argued that teachers' barriers to CLIL lie in the need for collaboration with others, which requires time and planning. Due to a lack of relevant materials and resources, most CLIL teachers are also necessarily confronted with balancing content and language (Bovelann, 2014; Steiert & Massler, 2011).

CLIL, EMI and CBI: The same or different?

Over the last few decades, there has been a huge change internationally, shifting from teaching English as a foreign language (EFL) to using English as a medium of instruction (EMI). In this regard, innovative approaches like CLIL, Content-Based Instruction (CBI), and EMI have been introduced (e.g., Cenoz, 2015; Marsh, 2008; Stoller, 2008). However, these terms share several essential and overlapping characteristics, which are not exactly interchangeable. That is, both CLIL and CBI refer to pedagogical programmes in which academic content is taught through a second or additional language. However, the CBI is an approach to language teaching that provides students with authentic language input using content, texts, exercises, and tasks derived from the subject matter topics, whereas CLIL is a teaching and learning approach that emphasizes the dual processes of language and content. It aims to explicitly advance both the students' language and content knowledge.

Although these approaches aim to integrate language and content instruction (Mehisto et al., 2008), they are not always used in the same way. CLIL and CBI programmes do not come from the same historical or ideological framework. CLIL originated in Europe, where English has often been used as a medium of instruction in CLIL classrooms (Dalton-Puffer, 2007), whereas CBI originated in the bilingual contexts of Canadian immersion programmes (Stoller, 2008). Also, CBI and CLIL are differently implemented. CLIL is defined as a set of techniques that lead to dual-focused instruction with emphasis on both content and language (Marsh, 2008). By focusing on the four key elements of CLIL teaching -- Content, Communication, Cognition, and Culture or four C's (see Figure 1), content and language can be integrated. The integration

of content and language is therefore essential for any application of CLIL approach (Llinares & Morton, 2017). In order to facilitate students' meaningful input and output in L2, the teaching method draws extensively on constructivist and socio-cultural learning concepts. In other words, CLIL does not preclude the use of the learners' native language, which has been shown to promote intercultural competence while improving language skills. In contrast, CBI is an umbrella term that encompasses dual-teaching approaches where the balance of emphasis placed on language and content teaching might vary (Stoller, 2008). The goal of CBI, in essence, is to improve language-learning outcomes. Content can be seen as a means of providing meaningful input (Butler, 2005) or as a purposeful source of authenticity, which is an important stimulus for language learning (Edsall & Saito, 2012).

Similarly, Dearden and Macara (2016) pointed out that EMI is another umbrella term for academic courses taught in English regardless of any clear goal for improving students' English language skills. However, Brown & Bradford (2017) considered EMI a different approach to English language teaching from CLIL and CBI, rather than as an umbrella term. EMI refers to the use of English for teaching academic subjects in countries where English is not a first language of the majority of the population (Dearden, 2015). In this regard, EMI only uses English as the medium of instruction and its primary goal is content learning. Therefore, the focus of EMI is on "students' content mastery and no language aims are specified" (Unterberger & Wilhelmer, 2011, p. 96). Moreover, according to Brown (2014), English in EMI is seen primarily as a tool for content delivery and language learning for an implicit or incidental outcome. In this respect, both the learning outcomes and assessment are closely linked to the subject's content.

Despite some overlaps and differences between these three instructional approaches, CLIL has a dual focus on content and language; in EMI, content is central; and in CBI, content serves as a vehicle for language learning, and the outcomes of content learning are incidental. In short, "content" is the element that the three approaches have in common. What separates them, however, is the way in which content is taught, which may involve a native language, exclude it, or use content for accessing academic knowledge or for communicative purposes. It is therefore important for language and content teachers as well as other stakeholders to understand the role that language and academic content play in CLIL, CBI and EMI so that they can best support their students' learning objectives.

Considering the literature reviewed on the purported benefits and challenges of CLIL, the present study sets out to investigate the benefits of CLIL instruction in conjunction with some challenges and concerns that teachers need to understand for the successful implementation of CLIL. It also ascertains students' attitudes towards language learning in a CLIL context. This study raises several issues regarding strengths and possible weaknesses that will lead to a better understanding of how CLIL works and consequently its rigorous implementation.

Methods

Research design

This research employed a mixed qualitative and quantitative methods. Qualitative data were from the research abstracts produced by the students participating in this study, and the data obtained from interviews to delve into the benefits and challenges faced by content teachers taking part in CLIL implementation. Quantitative data were from a Likert scale questionnaire completed by the student participants focusing on self-assessment of knowledge prior to and perceived satisfaction after CLIL instruction.

Participants and setting

This small-scale case study was conducted at a medium-sized university in Thailand. Since CLIL lessons are not compulsory in higher education in Thailand, receiving permission and collaborating with the content teachers and language teachers was imperative. The English language teachers referred to here were the researchers themselves, while content teachers were those teaching the courses using the English language. Specifically, in executing CLIL instruction in the classroom, six content teachers and 24 students in the fields of science, chemistry, biology, physics, and entomology, voluntarily participated. Regarding ethical considerations, the researchers informed the participants about the purpose of the study, the way in which the study results would be disseminated, their rights and the possibility of withdrawing from the study. Each participant was assigned a pseudonym to protect their anonymity. The information was kept confidential in a secure electronic folder. They were also asked to sign a consent form before participating in the present study.

These participants were selected based on convenience sampling. As for the students, they are all monolingual speakers of Thai with ages ranging from 20 to 23 years. These students had no previous experience in studying English in any English-speaking country, and their English proficiency was at an intermediate level. It should be noted that this study did not consider other aspects relating to these students, such as their grade point average, and previous amount of English instruction received. Among the participating teachers, three hold PhDs from Thailand, whereas the three others received their PhDs abroad, which is noteworthy because their English competencies and implementation of teaching strategies arise from a different set of experience. All six teachers involved in the study had between ten to fifteen years of teaching experience. However, they had no previous experience teaching science or any other subject through the medium of English, nor did they have experience with CLIL. At this juncture, although these six subject content teachers are not proficient or C1/C2 speakers based on the Common European Framework of Reference for Languages (CEFR) which is used to evaluate an individual's language proficiency, they have substantial exposure to the English language. For example, they have experiences in scholarly publication in English, reading and writing research reports, and articles in English, and participating in and presenting scientific papers in English at national and international conferences. In this study, these six content-subject teachers were assigned as CLIL teachers for six weeks of CLIL instruction.

At the time of the study, all fourth-year student participants (24 students) were enrolled in a "special problem" course, which required them to conduct a scientific study and write both a research report and an abstract in English. Students were permitted to produce multiple drafts if necessary. However, at the end of the semester, they were required to submit a final research report including a research abstract. Thus, the drafts were subject to change based on the commentary and assertions of the content teachers. Although there were no conventional classes or lessons, laboratory progress could be shared in tutorial sessions during the teachers' consultation hours. In such cases, teachers provided comments, constructive feedback, and revisions of some linguistic aspects to encourage progress in the research study.

Research instruments and materials

A range of approaches to data collection were employed to capture the breadth of participants' experiences – both that of teachers and students-- in CLIL implementation. To assess the benefits of CLIL instruction and challenges faced by content teachers, semi-structured interviews were conducted with the teachers and the students. For the teachers, three semi-structured focus group interviews involving the six content teachers were conducted approximately one week after the project's completion to obtain information about their attitudes towards the CLIL implementation and to elicit perceived benefits and challenges concerning the CLIL instructions. These interviews in Thai were audio-recorded and lasted approximately 30 minutes each. Thus, the original excerpts included in this article have been translated from Thai. Such exchanges allowed for an in-depth investigation of a number of topics covered in the CLIL project. The main themes explored were the teachers' experiences and perspectives about the CLIL process and the lessons in general as well as the challenges encountered during the project; for example, (1)*"What do you think about the CLIL lessons?"*, or (2) *"What is your most important concern regarding these lessons?"*.

For the students, the semi-structured interviews were conducted with six of the 24 students, selected on a voluntary basis, to assess what they had learned in the course and to collect information about their attitudes towards CLIL learning. The interview questions encouraged students to reflect on their CLIL learning experience; for example: (1) *"What did you like the most?"*, (2) *"What were the main difficulties?", or* (3) *"What did you learn to do better?"* Each interview lasted approximately 20 minutes.

To determine students' CLIL instruction satisfaction, a Likert scale with items was developed to elicit students' English proficiency and their attitudes towards CLIL instruction through a self-rating before CLIL lessons. The questionnaires were completed both prior to and after CLIL instruction (see Appendix 1).

Procedure

Before any data collection could start, developing CLIL materials to be used in the study was considered since there is a shortage of materials and teaching resources specifically created for CLIL in specific EFL contexts (Mehisto et al., 2008; Stoller, 2004;). Therefore, the CLIL materials had to be adapted to the corresponding subjects, thereby creating CLIL materials that addressed the course objectives.

In developing the CLIL materials for this study, fourteen research articles were carefully selected based on their research content and validated by the content teachers and the researchers to affirm they concurred with the scientific language, such as terms and expressions, relevant to the conduct of scientific experiments and course objectives. These articles also needed to correspond to the major sections of a research article:

Abstract, Introduction, Methods, Results, Discussion or Abstract-IMRD[5]. They were first categorised and identified based on the type of core components or rhetorical structure, as well as their linguistic features and lexical items related to the students' research experiment. In this regard, the analysis, design, and development of the CLIL materials employed in the present study were based on Swales' (2004) ESP-genre analysis and Kanoksilapatham's (2015) work. The aim was to check that these newly created materials, which correspond to Meyer's (2010) CLIL pyramid, addressed the current need for context-responsive materials involving scientific experiments and course objectives. To that end, five elements frequently found in abstracts were identified as Background, Purpose, Methods, Results, and Discussion. As for the other sections, three elements were distinguished in the Introduction, another three in the Method, one in the Results, and lastly eight in the Discussion. These genre-specific elements related to scientific writing were directly applied to the instructional CLIL materials (see Appendix 2 for examples). The instructional materials used were intended to facilitate students' learning of the necessary vocabulary and linguistic features they needed to express their ideas and understand the subject matter, while fostering cooperative learning and contributing to the development of metalinguistic skills, which was the main priority of the intervention. Additionally, the language elements of each section focused on developing their reading and writing skills as well as their ability to identify the main elements to be included in each section of the article's. Ultimately, the students had to apply this knowledge to their written research report at the conclusion of the study.

Sequence of the CLIL implementation

Once the CLIL instruction materials had been prepared, the researchers (as language teachers) facilitated training sessions for the content teachers, which mainly focused on how to implement the materials. Another essential component was the key linguistic elements in the article sections that were necessary to comprehend the research contents uncovered by the analysis. All discussions and negotiations regarding the CLIL methods as well as explanations and feedback provided to students were considered. The training occurred twice before and then twice again during the CLIL instructions. The aim of this training was to prepare and support the content teachers in their delivery of lessons, implementation of the CLIL materials, and demonstration of activities through the medium of English to familiarise them with the content to be taught when implemented in English. The CLIL approach can be said to strengthen collaboration among content teachers and language teachers by supporting and troubleshooting lesson plans, language issues, and the development of the CLIL materials and, furthermore, training before their implementation to complement particular subject matters (Dale & Tanner, 2012).

The CLIL instructions delivered in English took place over a six-week period during the second semester of the 2019 academic year. In the first half of the semester, students explored scientific themes and conducted a laboratory experiment in exclusive consultation only with the content teachers. After midterm exams, the CLIL instructions were initiated, and the students were encouraged to write research progress reports. During this seven-week period of tutorial sessions, they reported laboratory progress and discussed the experiment's results with their content teacher in English. These meetings took approximately two hours per week for a six-week period. At this stage, the developed CLIL materials provided students with a rich experience of authentic language use to evoke their curiosity about language use in individual article sections of Abstract-IMRD. Their learning was facilitated by allowing them to actively engage with the given activities, hands-on tasks involving collaborative problem-solving exercises to further develop their interaction skills. Finally, Week 7 was reserved for the submission of the abstract, final research report, and questionnaire distribution to elicit the students' opinions and perceptions of the CLIL implementation.

Data collection and analysis

During the CLIL lessons, students were required to write a research abstract for their scientific research topic of interest in addition to progress reports about their experiments. In parallel, they attended tutorial sessions during which they received feedback on how to strengthen the quality of their research and writing skills. The language used in these sessions were English. Audio-recorded dictations, and field notes completed by the researcher were also used and incorporated in these tutorials. All the research abstracts (first and final drafts) produced by the students were collected and qualitatively analysed using Swales' (2014) move analysis.

[5] The scholarly document adheres to the typical "IMRD" format, which comprises four main sections: Introduction, Methods, Results and Discussion. This format is generally used when writing laboratory reports and documenting systematic investigations in the social sciences, natural sciences, engineering, and computer sciences. Scholarly publications also use this format.

To examine the benefits of the CLIL implementation, six subject content teachers were invited to have a focus-group interview. Their responses from the focus group interview were thematically analysed, which made it possible for the researchers to discern the teachers' individual CLIL teaching experiences and what value they attached to them. To this end, the researchers broadened meanings and concepts into categories during axial coding. Selective coding was utilised to write the story and put the finishing touches on grounded theory. The researchers ended their data analysis when theoretical saturation had been achieved, that is when no further concepts or information emerged from the data (Johnson & Christensen, 2019).

To assess whether the students were satisfied with CLIL instruction, 24 students completed the questionnaire administered prior to and after the instruction. Each question was rated on the five points Likert scale (Strongly Agree (5), Agree (4), Somewhat Agree (3), Disagree (2), and Strongly Disagree (1)). The data were collected and quantitatively analysed to determine students' level of English proficiency and their perceptions of CLIL lessons. In addition, six of the 24 students were asked for an interview to further elicit their opinions regarding their CLIL experience satisfaction. Like the content teachers' interviews, the interviews with the students were audio-recorded, and the data collected were coded according to the themes that emerged.

Findings

Student's language abilities

An analysis of the students' abstracts showed an improvement in the number and variety of specific vocabulary units or lexical items used in their compositions. Figure 2 shows that the students' knowledge of rhetorical structure and organisation of ideas improved substantially. Two abstract drafts by one of the students were compared to highlight the development of writing skills regarding generic form, language used to express ideas, and rhetorical organisation.

First draft

The Pechmann condensation reaction is condensation reaction between phenol or phenol derivatives and β-ketoesters. This reaction is conducted at high temperature and used strong acidic condition. In normally, homogeneous catalyst is used in this reaction but it have major drawback such as it need to use large quantity to provide the high yield of product, toxicity and it can't reuse for the reaction according to in this study interested about heterogeneous catalyst, which must be resolve the major drawback of homogeneous catalyst. Zeolite is heterogeneous catalyst, which can resolve many problem of homogeneous catalyst. This study used the H-Beta zeolite as a catalyst for the reaction and studied about the potential of H-Bata zeolite by examined the recyclability of H-Beta zeolite. In addition, this research also determined the activation energy of the reaction and studied about the mechanism of the reaction by computational calculation.

Final draft

The Pechmann condensation reaction is condensation reaction between phenol or phenol derivatives and β-ketoesters. This reaction is conducted in strong acidic condition. In normally, homogeneous catalyst is used for this reaction but it have major drawback, accordingly in this research interested about heterogeneous catalyst, which must be resolve the major drawback of homogeneous catalyst. In this study focus on the H-Beta zeolite, which is heterogeneous catalyst for the reaction between resorcinol and ethylacetoacetate at different temperature between 353-453 K and also identify the activation energy of the reaction by using the Arrhenius equation and the mechanism of the reaction was calculate by using the Density Functional Theory with the M06-2X functional. The experimental result reveal that the activation energy of the reaction is 5.33 kcal/mol and optimum temperature of the reaction is 413 K, which provided the highest % yield of product around 71.89 % and the examined of recyclability test found that H-Beta zeolite can be reuse for the reaction as many as 4 cycle. The computational calculation result reveal that the mechanism of the reaction consisted 3 consecutive steps is transesterification, Intramolecular hydroxyalkylation and Dehydration. The tansesterification was as the rate-determining step of the reaction

Figure 2: Examples of a student's abstracts written in English

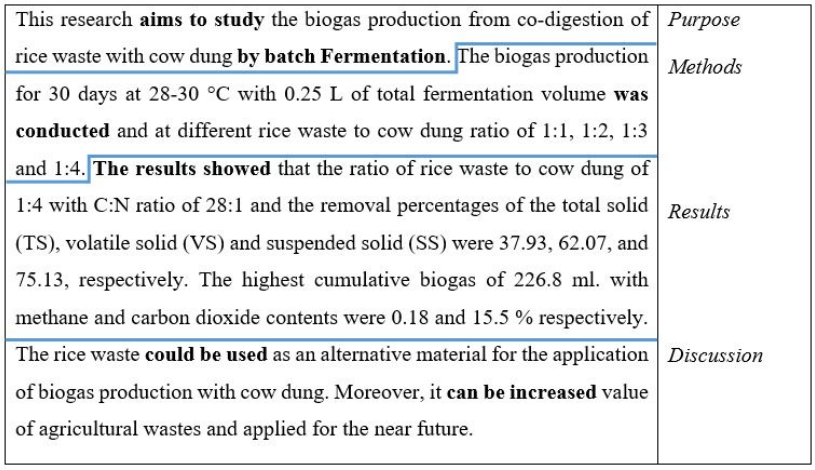
Figure 2 shows that both the structure and language used are more comprehensible when taught alongside the subject matter's content. In this regard, when the first draft was written before the week of CLIL sessions, students may have only known the fundamentals of research methodology they had used and/or adopted in their research and experiments, and justifications for selecting methodologies. Then during the CLIL sessions, the drafts were developed and improved as integrating both content and language skills and using them in improving abstract writing as the target of learning. Given that students had the opportunity to read authentic academic texts and reflect on their ideas during CLIL lessons, it is conceivable that they applied their newly acquired knowledge to the content's refinement to more closely align with their abstracts. In terms of content, tutorial activities such as supervising scientific experiments, following-up research progress, discussing and presenting issues related to the scientific field, reading research articles focusing on language and expressions in writing research papers and different sections of IMRD articles could also help develop the language especially scientific words and content of the abstract. It can be said that these activities using Swales' (2004) genre-based approach provided by the content teachers during the six weeks of CLIL instruction, apart from language development, the final draft therefore shows to be more advanced in both content and language skills than the first draft shown in Figure 2. This finding corresponds with Anagnostou et al. (2016) and Papadopoulos and Griva (2014) in that CLIL instruction can enhance students' comprehensible skills and productive skills. Of course, this may not have been possible without the help of the content teachers in the tutorial sessions. Therefore, it is possible that the language feedback and the laboratory work as 'content knowledge' played a significant role in this study.

Regarding the vocabulary and rhetorical structures applied to abstract writing, one of the students' works revealed some interesting differences. As can be seen in Figure 3, the text segment concerning discussion of the study reported appeared in the final abstract draft. It is possible that by the end of the course, the student was able to apply knowledge of the organisational structure commonly found in research abstracts after being exposed to instructional materials, using Swales' (2014) genre analysis, created by English language teachers and content teachers (as shown in Appendix 2). Regarding lexical choices, it is evident that the expression *'by batch fermentation'*, which is considered an important phrase of the study, was added. This addition has a great impact on the reader's understanding of the abstract. In accordance with the experiment's results, the text segments indicating the study's Methods and Results were respectively different in terms of their rhetorical structure. However, the Discussion section was added to the final draft with the use of *'could be used'* as one of the hedge expressions to express hesitation or uncertainty as well as to demonstrate deference and courtesy in making a claim. According to Hyland (1996), hedges are linguistic devices and strategies that enable writers to properly modulate their positions and claims. They provide the reader with the opportunity to participate in a dialogue and a proposition. In addition, writers use hedging devices to qualify their statements, thereby reducing the risk of opposition. They are strategies that let readers know that they do not claim to have the final word on the subject as it remains open for further discussion. In this regard, as used in the CLIL sessions and activities provided, the grammatical and lexical features associated with different elements of the abstract which were highlighted in the instructional materials, including past tense, passive voice, sentence completion, rearrangement and move identification could have had a great impact on improving the abstract drafts. This could at least facilitate exposure to content and language knowledge at a level just beyond the students' current knowledge (De Graff et al., 2007).

First draft

This research **aims to study** the biogas production from co-digestion of rice waste with cow dung by anaerobic digestion. The purpose of this research was to study the potential of rice waste to cow dung for biogas production and the factors that affect the rate of biogas production.	*Purpose*
The biogas production in batch digestion for 30 days at 28-30 °C with 0.25 L of total fermentation volume **was conducted** and at different addition 1:1, 1:2, 1:3 and 1:4.	*Methods*
The results showed that the ratio of rice waste to cow dung of 1:4 with C:N ratio of 28:1 gave the highest cumulative biogas of 226.8 ml. Methane and carbon dioxide contents were 0.18 and15.5 % Moreover, the removal percentages of the total solid (TS), volatile solid (VS), suspended solid (SS) and COD were 37.93, 62.07, 75.13 and 88.55, respectively.	*Results*

Final draft



This research **aims to study** the biogas production from co-digestion of rice waste with cow dung **by batch Fermentation**. The biogas production for 30 days at 28-30 °C with 0.25 L of total fermentation volume **was conducted** and at different rice waste to cow dung ratio of 1:1, 1:2, 1:3 and 1:4. **The results showed** that the ratio of rice waste to cow dung of 1:4 with C:N ratio of 28:1 and the removal percentages of the total solid (TS), volatile solid (VS) and suspended solid (SS) were 37.93, 62.07, and 75.13, respectively. The highest cumulative biogas of 226.8 ml. with methane and carbon dioxide contents were 0.18 and 15.5 % respectively.	*Purpose* *Methods* *Results*
The rice waste **could be used** as an alternative material for the application of biogas production with cow dung. Moreover, it **can be increased** value of agricultural wastes and applied for the near future.	*Discussion*

Figure 3: Changes observed in a student's first abstract draft written in English

This finding is consistent with Anagnostou et al. (2016) and Papadopoulos and Griva (2014) and Dalton-Puffer (2007) who confirmed that CLIL instruction helped students express their ideas through extensive vocabulary and, most likely, used it in more complex ways.

The voices of content teachers

Importance of language and training sessions

English language competence and step-by-step procedures are considered vital for implementing CLIL in authentic classroom settings. The interviews indicated that all teachers who participated in this study agreed that the training sessions were essential because they allowed them to understand what had to be done in addition to simply focusing on the content. In their interviews, they mentioned a more balanced development of the content's information and knowledge to be taught and described all English communication skills as "crucial" in CLIL classrooms. They also reported that, despite the initial discomfort of presenting the content in English, they did appreciate the opportunity to teach the lessons in English, which made them feel more confident afterwards. When asked, *"How do you feel when you teach the content in English?"* one teacher's response reflected this as follows:

> *I admitted that I had to prepare a lot before the tutorial session, both about scientific study of my students and the English language. This is because I did not get my degree from abroad, but it is real fun. I had an opportunity to revise and practice my English. I think it is so much different from teaching* [the students] *as usual.* [T4]

It seems that although CLIL teaching and activities are perceived as fun and useful approach, the informant sheds light on feeling inferior in that she does not have a PhD from overseas. On the other hand, the teacher views CLIL implementation as an avenue to practise English.

Prior to CLIL implementation in this study, training sessions were conducted for the content teachers so that they could integrate and deliver the content of research, rhetorical knowledge, and the English language in their CLIL instruction smoothly and effectively. However, the training sessions for the content teachers were somewhat limited due to time constraints. Since the diverse subject matter and laboratory work were outside the language teachers' control, some content teachers perceived themselves as inadequately trained or prepared before the actual CLIL instruction. Therefore, some discussions addressed problems involving the application and usage of academic vocabulary in writing research abstracts. When asked, *"Do you have any problem about implementing CLIL in your tutorial sessions?"* two content teachers stressed certain aspects of CLIL instruction and the role of their training:

> *I am not sure whether the words used in the abstract are right. It is very good that we have a discussion after the training because I can ask you what it means by this and that. With the training I get some sort of sense of what it is in the abstract, how it is that a lesson can actually be taught so that I can integrate that with content as well.* [T3]
>
> *I think that teaching like this really needs good training and a lot of time to prepare because I have to study prior to a real class. I did not graduate from a university where English is used in teaching, so sometimes I have to think a lot which words I have to use when explaining the content to my students. However, teaching with the CLIL approach is fun. I can practice my English skills, too*. [T4]

These teachers suggest that well-organized training, relevant objectives in CLIL teaching, and learning which teachers can be cautiously initiated with CLIL implementation for the delivery of lessons. This finding is in accordance with the recommendation by Butler (2005), McDougald (2015), and Spratt (2012) in that special training should be provided based on the demand for planning and outlining CLIL lessons. The knowledge and training of CLIL teachers plays a critical role in providing rich and supportive target-language environment. According to Mehisto et al. (2008), the main objectives of CLIL training is to ensure that teachers can make input intelligible, use teacher-talk effectively, guide students' comprehensible output, and respond to the diverse needs of students. The findings of the current study regarding teachers' perceptions and challenges clearly underline the value of both content and language skills for CLIL teachers. Based on what the CLIL teachers encountered, it is suggested that before CLIL is fully implemented, adequate and effective CLIL training sessions need to be provided in order to prepare or and/or address the issues experienced by CLIL teachers. Meanwhile, both CLIL teachers and students need to acquire a sufficient level of English proficiency from the outset in order to achieve the dual goal of content learning and development of English language skills. As in this study, it is argued that without sufficient language competence in the instruction, content teachers possibly have difficulty in engaging students in complex cognitive processes, scaffolding their efforts to master knowledge or providing rich language input to concurrently develop students' language proficiency and teach the required content.

> *When asked further about the use of CLIL material in the intervention, such as "What do you think about creating CLIL materials and using them in class?" two of the content teachers admitted that creating CLIL material was very difficult because they needed a systematic plan to integrate the content and language learning with the process of selecting texts and information. This process also included a methodological design to be used from the immediate outset. I didn't know that we would have to prepare a lot creating the teaching material. I normally ask my students to read and follow the way the author writes an abstract. We then discuss why is this and that and make some changes according to the topic and the results of the laboratory.* [T4]

> *I think that some activities in the materials such as Methodology are not necessary. It does not fit teaching time. For the exercises of the Results section, they consume more time than what I have planned. I think we need well-planned activities, especially the time for each learning activities, which it would be best to try out everything before doing so in a real classroom setting*. [T5]

These excerpts indicate that the teachers want to have quality preparation and advice for designing, preparing, and using CLIL materials. Their responses clearly show that developing and accessing material designed for CLIL instruction is a challenge for content teachers. This finding is in line with Bovellan (2014) who concurred that preparing teaching material for CLIL is a challenging task for content teachers. Bovellan (2014) and Mehisto (2012) maintained that there appears to be a strong association between teaching materials used in the classroom and student learning outcome. As a result, the teacher's role in designing instructional materials is indispensable to the implementation of CLIL.

When asked to give suggestions for improving the CLIL lessons, compared to the "traditional" teaching they provided students before the experiment, two teachers offered the following ideas (among many others): using more group activities, discussions, and model texts to deliver content in CLIL instruction, as shown in these excerpts:

> *For me, this is a paradigm teaching approach. To be honest, I would need more time and extend this CLIL course because I think I have to prepare a lot before teaching. I also ask my students to discuss and compare their piece of work so that they can exchange their idea to correct and revise their work.* [T2]

> *Some exercises and excerpts presented in the material are quite broad and perhaps too general. In my class, I use additional abstracts and research articles to present to and teach my students as they are specific to the field and the work they are conducting. With this way, it can supplement and help me to explain how the language is used and save time in class. And if the students have some more questions concerning the content knowledge and the language, I usually ask them to do a group discussion and provide them with additional model texts*. [T3]

Since a content teacher must be language-aware and a language teacher must be content-aware in the CLIL approach, the teaching quality was a major concern in this study. Some of the content teachers held a doctoral degree from an English-speaking country and, thus, conducting tutorials in English and providing feedback on the students' tasks was not a problem. However, for those who were not proficient in English, using English undoubtedly hindered the students' understanding of the content. At this juncture, the group of teachers featured the target language support mostly through L1 translation and explanation. This fact has been discussed in previous studies (e.g., Coyle, 2008; Coyle et al., 2010; Dalton-Puffer, 2007; Escobar Urmeneta, 2019) which highlight the complexity of maintaining a balance between content and language in classroom instruction.

According to CLIL principles, a dual focus on the integration of content and language is emphasized. However, given the time constraints of this study, two of the content teachers mentioned that they did attain an adequate balance between content and language, but they were unsure as to how these two main focal points were maintained in practice. When asked, *"Do you have any problem about using English in your tutorial sessions?"* they reflected as follows:

> *When I have a tutorial with my student, sometimes I cannot think of the correct words to be used to explain to her. So, I switch my language into Thai, rather than English. And sometimes, I think the language used in the student's work is fine, but some content should be revised and fixed. I am not sure how I can explain to her and how I can control myself to balance between the revision and the English language.* [T5]

> *Sometimes I am not sure what I should focus on my explanation between the detail of my student's experiment and the language use because my student made mistakes in both content and language. I am quite confused how I can explain and clarify her work.* [T6]

The teachers' responses above indicate that the limits of language usage influence the degree of content differentiation and challenge offered. This fact reflects their understanding of language barriers and difficulties in expressing scientific ideas in English. In other words, the language issue seems to be dominant when teaching CLIL. Teaching with CLIL materials tuned into explicit instruction of English language skills for the content teachers, English can become a barrier when it comes to successfully presenting lessons to students in CLIL classes. These excerpts also underscore the importance of CLIL teachers who are expected to act not only as reflective practitioners but also as language experts creating environments in which students can simultaneously expand their knowledge and language skills. In this regard, content teachers must perceive themselves as both content and language teachers given that content and language need to be balanced.

Students' level of satisfaction and the impact on motivation

The questionnaires were self-rated by all 24 of the students participating in the CLIL lessons and required them to assess their English proficiency and provide opinions of CLIL instruction both before and after the intervention. The findings revealed that students were satisfied with the CLIL project overall and acknowledged it as beneficial, especially in terms of organising ideas and improving their skills in reading and writing abstracts. Table 1 shows how the students rated their English proficiency and perceptions of CLIL lessons.

Items	Before the CLIL (N = 24)	After the CLIL (N = 24)
1. English proficiency in general	3.33	3.67
2. English listening skills	3.17	3.17
3. English speaking skills	2.50	2.50
4. English reading skills	3.17	3.17
5. English writing skills	2.50	2.83
6. Reading ability of academic articles in English	2.83	3.17
7. Ability in academic vocabulary	2.33	3.00
8. Knowledge of rhetorical structure in academic articles written in English	2.33	2.67
9. Reading ability of research abstracts in English	2.83	3.17
10.Writing ability of research abstracts in English	2.17	2.83

Table 1: Self-rating of students' English proficiency and CLIL lessons

As Table 1 indicates, most average scores from the questionnaires were higher after CLIL instruction, showing positive reformation and confirming previous studies, such as Fuchs (2015), Lasagabaster (2011) and Mearns (2015). Specifically, the students perceived that their English knowledge in general had improved following the CLIL lessons (from 3.33 to 3.67). They also reported that their knowledge of academic vocabulary had improved (from 2.33 to 3.00) alongside their ability in reading academic articles in (from 2.83 to 3.17). Interestingly, they rated their ability in reading and writing abstracts in English as enhanced by CLIL learning (from 2.83 to 3.17 and from 2.17 to 2.83 respectively). Regarding knowledge of structural patterns in research articles in English, the students affirmed that their understanding of how academic articles were constructed increased (from 2.33 to 2.67).

The interview results are further evidence of CLIL's positive impact on the students' motivation to improve their English. Most students viewed CLIL classes as more beneficial, and they felt more involved in the learning process. The interviews revealed that all students agreed that the CLIL lessons had helped them form a more positive attitude towards language learning. As four of the students stated:

> *It is good that my teacher points out what I have to revise or rewrite in my abstract draft. Her comments are pretty much similar to the ones I have found in the lessons which I had already forgotten. I think this is good, and I want to know more how to improve the quality of my work. I need to improve my English skills, too.* [S1]
>
> *I have a feeling that with teaching like this, I can use words and vocabulary that I have never known or studied before in my writing. The materials used make me understand how to use appropriate expressions in each element of the abstract written in English. But some activities are too easy in my thought, such as Methodology and Results.* [S2]
>
> *I think assigning students to read abstracts in English before teaching how to write ours together with explaining and pointing each necessary element of an abstract could help me writing an abstract of my research. I think I can read research abstracts and articles better than before. I like learning with this teaching.* [S4]
>
> *After learning with this approach, I think I can improve my English skills, and I now realize how to use words and necessary expressions in each section of the research articles and abstracts.* [S6]

The excerpts above indicate that the students appreciated the extension of their knowledge for revising the abstract draft after learning words, expressions, and language that should be included in their writing. Moreover, the students' motivation increased because the language was experienced in an academic setting, contributing to natural language acquisition rather than enforced learning. However, this finding is not consistent with Sylvén and Thompson's (2015) work that found no conclusive evidence for CLIL instruction generating more positive attitudes towards learning English or even boosting self-confidence for L2 use. More specifically, they suggested that CLIL could not be identified as the cause of students' motivation since the students observed in their study were already keen language learners even prior to their participation in CLIL programmes.

Discussion

This study aimed to identify the effectiveness of CLIL implementation in teaching to university science students how to write research abstracts and research reports. It also investigated challenges that content-teachers encountered when conducting CLIL classes. The results obtained from the questionnaires show a positive attitude and a satisfactory opinion regarding CLIL implementation in addition to an improvement of students' English proficiency after instruction. Based upon students' abstracts, it can be said that it is more feasible to teach rhetorical structure and language use alongside the content of the subject matter because students seemed to have greater confidence in the language and subject. These findings confirmed our initial expectations drawn from many other similar research studies (e.g., Dalton-Puffer, 2011; Fuchs, 2015) demonstrating that students' language proficiency, self-confidence, and general competence increased as a result of CLIL instruction. Some examples of these improvements are fluency and lexical and syntactic complexity (Pérez-Vidal & Roquet, 2015).

As reflected in the abstract drafts, apart from lexical complexity, the content included in the final drafts was substantially improved, compared to their first draft. It cannot be denied that CLIL activities, student-teacher negotiation and discussion, and teacher feedback can facilitate the learning and writing process through negotiated interaction. Through CLIL implementation, the students who participated in this study could learn through questions, discussion, presentation, negotiation of intended meaning and rhetorical pattern from genre knowledge and the power of Swales' (2014) move analysis itself in improving their abstract drafts. These experiences during the teacher-student interactions in the study are essential as they not only contribute to learning, but also enhance or transform the value of learning through the integration of content and language. At this point, as challenged by Meyer (2010), we acknowledge the need for close collaboration between language teachers and CLIL content teachers to create or adapt their own instructional materials, and the need for instructional design models that can guide them in doing so. Moreover, the sequence of lessons in the instructional materials should be carefully and systematically planned and taught in CLIL instruction.

It is evident that teachers' content knowledge and their language abilities are important factors influencing the effectiveness of CLIL instruction. The qualitative data revealed the fact that the challenges faced by CLIL teachers include not only the understanding of the subject's contents covered in the course, but also the requirement to use appropriate language to convey specific ideas (Seah et al., 2015). As such, teachers seem to be more aware of the importance of language as a key tool in the dual approach when they integrate both content and language in the classroom. Pérez Agustín (2019) and Escobar Urmeneta and Evnitskaya (2014) also point out that CLIL teachers should develop balance between language and content in a creative way and be able to expand students' active discipline-specific vocabulary by combining teaching methods – from reproductive to productive exercises, from ensuring satisfactory comprehension to content through language production. In this regard, Coyle et al. (2010) suggested that specialised knowledge in the field

as well as language knowledge and skills in presenting and delivering content, promoting students' understanding, and using vocabulary in a foreign language within a particular content are needed for CLIL implementation to strengthen and enhance the quality and effectiveness of CLIL instruction.

Training has been shown to be important for CLIL implementation to ensure that meaningful learning takes place and for instructional materials to yield positive results. As yielded from this study, even though the researchers as language teachers collaborated with the content teachers to design CLIL materials and activities and hold training sessions for them before the full CLIL implementation, the use of English perhaps become a barrier in CLIL teaching for some content teachers. For successful CLIL implementation, it is recommended that CLIL training, including subject-content delivery and teaching methods through language input, systematic instructional and linguistic support, is substantially needed for content teachers and CLIL teachers. In this regard, Pérez-Cañado (2018) discusses key competencies for CLIL teachers' skills, including linguistics competence, scientific knowledge, methodology, organisational, interpersonal, and collaborative skills, and continuing professional development. Moreover, CLIL teachers should have linguistic training within the subject taught through a second language (Doiz & Lasagabaster, 2020; Volchenkova & Bryan, 2019).

In addition, to successfully establish negotiated goals of CLIL implementation at large, the finding of the present study suggests that collaboration between subject teachers and language teachers or English language specialists for the context of this study is effective in improving the quality of material development and classroom instruction. To this end, it is appropriate to provide teachers with training for CLIL classes that consists of knowledge about the CLIL approach for both teaching and learning processes and the quality of the content learned. In addition, policy makers and educators alike need to deliberate its introduction and assess its efficacy in order to mitigate the linguistic issues in the typical CLIL setting (Kim & Kim, 2020). Hillyard (2011) also recommended that CLIL teachers change their perceived role. Taking into account the affective aspect of learning, CLIL teachers should be trained to become knowledgeable and sensitive to both content and language. The training must include appropriate assessment and evaluation procedures to be applied in the CLIL approach. Moreover, teachers must keep up with current advances in the field and, thus, apply new technology resources to the development of interactive methodologies in CLIL implementation (Escobar Urmeneta, 2019).

In addition, since CLIL provides opportunities for students to engage with the content taught, the findings of this study confirm that the implementation of CLIL could improve students' language skills, especially vocabulary use and English writing skills. However, even if CLIL principles have a systematic practice in the classroom, the feasibility of adapting the CLIL approach for students in a different setting is important. Moreover, as Marsh (2002) points out, CLIL is used as "a tool in the learning of a non-language subject in which both language and the subject have a joint role" (p. 58). Thus, it can be argued that the CLIL may not differ from foreign language teaching, where teachers can use a variety of approaches, media, or teaching strategies to help improve students' language skills and communicative competence. In this case, instructional materials and teaching strategies provided by subject-content teachers can have a great impact on the CLIL implementation.

Although this presents a small-scale study conducted within half of a semester, it has provided insights into the pressures and concerns of content teachers and language teachers involved in CLIL collaboration. Since this study revealed that training and collaboration between language teachers and content teachers in terms of the development and language used in the teaching materials are crucial in CLIL implementation, this finding offers important ideas and implications for the collaboration between education programmes and planners. Tan (2011) suggested that collaboration may begin with content subject teachers asking L2 teachers for help and advice on developing materials and well-defined instruction, which can subsequently develop into more in-depth collaboration such as cross-curricular planning or even co-teaching. Therefore, besides the cooperative efforts between language teachers and content teachers needed for developing teaching materials and cooperative instruction, support from programme planners, practitioners and experts is pivotal as they are an important part of a promising path through developing, inspiring, and providing CLIL learning environments as well as extending their professional capacities.

Conclusion

The present study's findings demonstrate the potential of CLIL as an effective approach to teaching science students at the tertiary level the intricacies of academic writing. Learning to write research reports and abstracts (together with scientific content) through the medium of the English language was considered a strength by both students and content teachers. The approach via the use of materials can create a

meaningful environment in which the students have to actively engage in the acquisition of knowledge for both scientific content and the English language. English proficiency, especially reading skills and the use of vocabulary in context, in addition to knowledge of specific content, was identified as a major issue in the discussions with students. Therefore, the CLIL approach can facilitate the focus on language skills and the increase of students' motivation in terms of both language and content learning. However, as content teachers pointed out, the implementation of CLIL depends on providing training sessions, close collaboration between content and language teachers, and maintaining a balance between content and language. Thus, qualified teachers and their required competencies, skills, content, and language knowledge, essential for effective CLIL implementation. They ensure that the appropriate and correct steps are taken in accordance with good CLIL principles and practice. Another challenge that content teachers encounter is the linguistic difficulty in expressing scientific ideas in English. In addition, students' linguistic competence is also of considerable concern in CLIL classrooms.

We submit that the length of exposure to CLIL instruction can shape positive learning outcomes. The present study, however, has some limitations. Its scope and scale were insufficient to examine all factors contributing to the success of the CLIL pedagogy and to extend knowledge about CLIL. In order to further investigate the effectiveness of CLIL instruction, a longitudinal CLIL study is recommended to shed light on student learning outcomes and for teachers to familiarise themselves with CLIL lessons and implementation. It might be helpful to use a mixed research design combining both quantitative and qualitative methods to obtain additional results on the impact of CLIL instructional practices. Furthermore, given the difference in educational systems and cultural specificities that might impact the success of any teaching programme, the local context needs to be taken into account when implementing CLIL in the classroom.

Acknowledgement

This research was supported by Thailand Research Fund under Grant No. RDG610030.

References

Anagnostou, E., Griva, E. & Kasvikis, K. (2016). From Michelangelo to Picasso: Implementing the CLIL approach in a foreign language project. In A. Murphy (Ed.), *New developments in foreign language learning* (pp. 150-168). Nova Science.

Banegas, D. L. (2011). Content and language integrated learning in Argentina 2008–2011. *Latin American Journal of Content and Language Integrated Learning, 4*(2), 33–50. https://doi.org/10.5294/laclil.2011.4.2.4

Bovellan, E. (2014). *Teachers' beliefs about learning and language as reflected in their views of teaching materials for content and language integrated learning (CLIL)* [Doctoral dissertation, University of Jyväskylä]. http://urn.fi/URN:ISBN:978-951-39-5809-1

Brown, H. (2014). Contextual factors driving the growth of undergraduate English-medium instruction programmes at universities in Japan. *The Asian Journal of Applied Linguistics, 1*(1), 50-63. https://caes.hku.hk/ajal/index.php/ajal/article/view/18

Brown, H., & Bradford, A. (2017). EMI, CLIL, & CBI: Differing approaches and goals. In P. Clement, A. Krause, & H. Brown (Eds.), *Transformation in language education* (pp. 328-334). JALT.

Butler, Y.G. (2005). Content-based instruction in EFL contexts: Considerations for effective implementation. *JALT Journal, 27*(2), 227-245. https://doi.org/10.37546/JALTJJ27.2-5

Cenoz, J. (2015). Content-based instruction and content and language integrated learning: The same or different? *Language, Culture and Curriculum, 28*(1), 8-24. https://doi.org/10.1080/07908318.2014.1000922

Coyle, D. (2008). CLIL - A pedagogical approach from the European perspective. In N. H. Hornberger (Ed.), *Encyclopedia of language and education*. Springer. https://doi.org/10.1007/978-0-387-30424-3_92

Coyle, D., Hood, P., & Marsh, D. (2010). *CLIL: Content and language integrated learning*. Cambridge University Press.

Coyle, D., & Meyer, O. (2020). Quality assurance in CLIL higher education: Priorities and challenges. In A. J. Martínez Agudo (Ed.), *Quality in TESOL and teacher education: From a results culture towards a quality culture* (pp. 159-170). Routledge.

Dale, L., & Tanner, R. (2012). *CLIL activities: A resource for subject and language teachers*. Cambridge University Press.

Dalton-Puffer, C. (2007). *Discourse in content and language integrated learning (CLIL) classrooms*. John Benjamins.

Dalton-Puffer, C. (2011). Content and language integrated learning: From practice to principles? *Annual Review of Applied Linguistics*, *31*, 182-204. https://doi.org/10.1017/S0267190511000092

Dalton-Puffer, C., Llinares, A., Lorenzo, F., & Nikula, T. (2014). "You can stand under my umbrella": Immersion, CLIL and bilingual education. A response to Cenoz, Genessee & Gorter (2013). *Applied Linguistics, 35*(2), 213–218. https://doi.org/10.1093/applin/amu010

Díaz Pérez, W., Fields, D. L., & Marsh, D. (2018). Innovations and challenges: Conceptualizing CLIL practice. *Theory into Practice, 57*(3), 177-184. https://doi.org/10.1080/00405841.2018.1484037

De Graaff, R., Koopman, G. J., Anikina, Y., & Westhoff, G. (2007). An observation tool for effective L2 pedagogy in content and language integrated learning (CLIL). *International Journal of Bilingual Education and Bilingualism, 10*(5), 603-624. https://doi.org/10.2167/beb462.0

Dearden, J. (2015). *English as a medium of instruction – A growing phenomenon*. British Council.

Dearden, J., & Macaro, E. (2016). Higher education teachers' attitudes towards English medium instruction: A three-country comparison. *Studies in Second Language Learning and Teaching, 6*(3), 455-486. https://doi.org/10.14746/sllt.2016.6.3.5

Doiz, A., & Lasagabaster, D. (2020). Dealing with language issues in English-medium instruction at university: A comprehensive approach. *International Journal of Bilingual Education and Bilingualism, 23*(3), 257-262. https://doi.org/10.1080/13670050.2020.1727409

Edsall, D., & Saito, Y. (2012). The motivational benefits of content. *OnCue Journal, 6*(2), 66-94. https://jaltcue.org/files/OnCUE/OCJ6.2/OCJ6.2_pp66-94_Edsall%26Saito.pdf

Escobar Urmeneta, C. (2019). An introduction to content and language integrated learning (CLIL) for teachers and teacher educators. *CLIL Journal of Innovation and Research in Plurilingual and Pluricultural Education, 2*(1), 7-19. https://doi.org/10.5565/rev/clil.21

Escobar Urmeneta, C., & Evnitskaya, N. (2014). 'Do you know Actimel?' The adaptive nature of dialogic teacher-led discussions in the CLIL science classroom: A case study. *The Language Learning Journal, 42*(2), 165-180. https://doi.org/10.1080/09571736.2014.889507

European Commission. (2003). *Promoting language learning and linguistic diversity: An action plan 2004-2006*. European Unit.

Fernández Fontecha, A. (2010). First steps of CLIL in a Spanish monolingual community: The case of La Rioja. In D. Lasagabaster & Y. Ruiz de Zarobe (Eds.), *CLIL in Spain: Implementation, results and teacher training* (pp. 79-94). Cambridge Scholars.

Fuchs, T. (2015). *Student motivation in CLIL-A case study in an upper secondary technical college in Austria* (Publication No. 12400392) [Master's thesis, University of Vienna]. U:theses. https://utheses.univie.ac.at/detail/32148

Gimeno, A., Ó Dónaill, C., & Zygmantaite, R. (2013). *CLILstore guidebook for teachers*. Retrieved from https://www.languages.dk/archive/tools/guides/ClilstoreGuidebook.pdf

Graddol, D. (2006). *Englishnext: Why global English may mean the end of 'English as a Foreign Language'*. British Council.

Griva, E., Chostelidou, D. & Semoglou, K. (2015). "Our neighbouring countries": Raising multicultural awareness through a CLIL project for young learners. In A. Akbarov (Ed.), *The practice of foreign language teaching: Theories and applications* (pp. 174-184). Cambridge Scholars.

Griva, E., & Kasvikis, K. (2015). CLIL in primary education: Possibilities and challenges for developing L2/FL skills, history understanding and cultural awareness. In N. Bakić-Mirić & D. Erkinovich Gaipov (Eds.), *Current trends and issues in education: An international dialogue* (pp. 125-140). Cambridge Scholars.

Hall, J. M., & Townsend, S. DC. (2019). Developing a theory of practice for CLIL with pre-service teachers. *Journal of the Japan CLIL Pedagogy Association*, *1*, 176-194.

Hillyard, S. (2011). First steps in CLIL: Training the teachers. *Latin American Journal of Content & Language Integrated Learning, 4*(2). https://doi.org/10.5294/laclil.2011.4.2.1

Hyland, K. (1996). Writing without conviction? Hedging in science research articles. *Applied Linguistics, 17*(4), 433-454. https://doi.org/10.1093/applin/17.4.433

Johnson, R. B., & Christensen, L. (2019). *Educational research: Quantitative, qualitative, and mixed approaches*. Sage.

Johnstone, R. (2000). Early language learning. In M. Byram (Ed.), *Encyclopedia of language teaching and learning* (pp. 188-193). Routledge.

Kanoksilapatham, B. (2015). Distinguishing textual features characterizing structural variation in research articles across three engineering sub-discipline corpora. *English for Specific Purposes*, *37*, 74-86. https://doi.org/10.1016/j.esp.2014.06.008

Kim, V., & Kim, J. (2020). Roles of teacher feedback in promoting effective English-medium instruction of a business subject. *The Journal of Asia TEFL, 17*(2), 319-757. http://dx.doi.org/10.18823/asiatefl.2020.17.3.9.889

Lasagabaster, D. (2008). Foreign language competence in content and language integrated courses. *The Open Applied Linguistics Journal, 1*, 30-41. https://doi.org/10.2174/1874913500801010030

Lasagabaster, D. (2011). English achievement and student motivation in CLIL and EFL settings. *Innovation in Language Learning and Teaching, 5*(1), 31-42. https://doi.org/10.1080/17501229.2010.519030

Lasagabaster, D. (2019). Motivation in content and language integrated learning (CLIL) research. In M. Lamb, Csizér, K., Henry, A., & Ryan, S. (Eds.), *The Palgrave handbook of motivation for language learning* (pp. 347-366). Palgrave Macmillan. https://doi.org/10.1007/978-3-030-28380-3_17

Lasagabaster, D., & Sierra, J. M. (2010). Immersion and CLIL in English: More differences than similarities. *ELT Journal, 64*(4), 367-375. https://doi.org/10.1093/elt/ccp082

Lee, J. (2020). Assessing the effects of CLIL on Korean high school students' writing. *Linguistic Research, 37*(Special Edition), 89-112.

Llinares, A. (2015). Integration in CLIL: A proposal to inform research and successful pedagogy. *Language, Culture and Curriculum, 28*(1), 58-73. https://doi.org/10.1080/07908318.2014.1000925

Llinares, A., & Morton, T. (2017). *Applied Linguistics perspectives on CLIL*. John Benjamins.

Llinares, A., Morton, T., & Whittaker, R. (2012). *The roles of language in CLIL*. Cambridge University Press.

Logioio, A. J. (2010). *Raising intercultural awareness at primary level through storytelling within a CLIL approach*. [Unpublished master's thesis] Universidade Nova de Lisboa. http://hdl.handle.net/10362/5699

Mackey, A. (2012). *Input, interaction, and corrective feedback in L2 learning*. Oxford University Press.

Marsh, D. (2002). CLIL/EMILE-The European dimension: Actions, trends and foresight. European Commission.

Marsh, D. (2008). Language awareness and CLIL. In J. Cenoz & N. H. Hornberger (Eds.), *Encyclopedia of language and education* (pp. 233-246). Springer.

Martínez Agudo, J. D. (2019). Which instructional programme (EFL or CLIL) results in better oral communicative competence? Updated empirical evidence from a monolingual context. *Linguistic and Education, 51*, 69-78. https://doi.org/10.1016/j.linged.2019.04.008

McDougald, J. S. (2015). Teachers´ attitudes, perceptions and experiences in CLIL: A look at content and language. *Colombia Applied Linguistics Journal, 17*(1), 25-41. https://doi.org/10.14483/udistrital.jour.calj.2015.1.a02

Mearns, T. L. (2015). *Chicken, egg or a bit of both? Motivation in bilingual education (TTO) in the Netherlands*. (Publication No. 646095) [Doctoral dissertation, University of Aberdeen]. EThOS.

Mehisto, P. (2008). CLIL counterweights: Recognising and decreasing disjuncture in CLIL. *International CLIL Research Journal, 1*(1), 93-119.

Mehisto, P. (2012). Criteria for producing CLIL learning material. *Encuentro, 21*, 15–33. https://files.eric.ed.gov/fulltext/ED539729.pdf

Mehisto, P., Marsh, D., & Frigols, M. (2008). *Uncovering CLILL: Content and language integrated learning in bilingual and multilingual education*. Macmillan.

Meyer, O. (2010). Towards quality-CLIL: Successful planning and teaching strategies. *Pulso, 33*, 11-29. https://doi.org/10.58265/pulso.5002

Morton, T., & Llinares, A. (2017). Content and language integrated learning (CLIL): Type of programme or pedagogical model? In A. Llinares & T. Morton (Eds.), *Applied linguistics perspectives on CLIL* (pp. 1-16). John Benjamins.

Nhan, T. (2013). Promoting content and language integrated learning in gifted high schools in Vietnam: Challenges and impacts. *Internet Journal of Language, Culture and Society, 38*, 146-153. https://aaref.com.au/wp-content/uploads/2018/05/37-17.-Thuy-Nhan-ok.pdf

Papadopoulos, I., & Griva, E. (2014). Learning in the traces of Greek Culture: A CLIL project for raising cultural awareness and developing L2 skills. *International Journal of Learning, Teaching and Educational Research, 8(1),* 76-92. https://www.ijlter.org/index.php/ijlter/article/view/168/65

Pérez Agustín, M. (2019). Meeting CLIL teachers' training and professional development needs. *NABE Journal of Research and Practice, 9*(3-4), 119-127. https://doi.org/10.1080/26390043.2019.1634961

Pérez Cañado, M. L. (2018). CLIL and pedagogical innovation: Fact or fiction? *International Journal of Applied Linguistics, 23*(3), 369-390. https://doi.org/10.1111/ijal.12208

Pérez-Vidal, C., & Roquet, H. (2015). CLIL in context: Profiling language abilities. In M. Juan-Garau & J. Salazar-Noguera (Eds.), *Content-based language learning in multilingual educational environments* (pp. 237–255). Springer.

Seah, L. H., Clarke, D., & Hart, C. (2015). Understanding middle school students' difficulties in explaining density differences from a language perspective. *International Journal of Science Education, 37*(14), 2386-2409. https://doi.org/10.1080/09500693.2015.1080879

Spratt, M. (2012). Comparing CLIL and ELT. In R. Popović & V. Savić (Eds.), *Content and Language Integrated Learning (CLIL) in Teaching English to Young Learners* (Conference Proceedings No. 11) (pp. 9-20). City Press.

Stathopoulou, M. (2015). Cross-language mediation in foreign language teaching and testing. Multilingual Matters.

Steiert, C., & Massler, U. (2011). Guidelines for evaluating and developing CLIL materials. In S. Georgious & P. Pavlou (Eds.), *Guidelines for CLIL Implementation in Primary and PrePrimary Education* (pp. 98-113). Education and Culture.

Stoller, F. L. (2008). Content-based instruction. In N. H. Hornberger (Ed.), *Encyclopaedia of language and education* (pp. 59-70). Springer.

Sudhoff, J. (2010). CLIL and intercultural communicative competence: Foundations and approaches towards a fusion. *International CLIL Research Journal, 1*(3), 30–37.

Swales, J. (2004). *Research genres: Explorations and applications*. Cambridge University Press.

Sylvén, L. K. (2013). CLIL in Sweden – Why does it not work? A metaperspective on CLIL across contexts in Europe. *International Journal of Bilingual Education and Bilingualism, 16*(3), 301-320. https://doi.org/10.1080/13670050.2013.777387

Sylvén, L. K., & Thompson, A. S. (2015). Language learning motivation and CLIL: Is there a connection? *Journal of Immersion and Content–Based Language Education, 3*(1), 28–50. https://doi.org/10.1075/jicb.3.1.02syl

Tan, M. (2011). Mathematics and science teachers' beliefs and practices regarding the teaching of language in content learning. *Language Teaching Research, 15*, 325-342. https://doi.org/10.1177/1362168811401153

Troncale, N. (2002). Content-based instruction, cooperative learning, and CALP instruction: Addressing the whole education of 7-12 ESL students. *Working Papers in TESOL & Applied Linguistics, 2*(3). https://doi.org/10.7916/D86T0M4D

Unterberger, B., & Wilhelmer, N. (2011). English-medium education in economics and business studies: Capturing the status quo at Austrian universities. *International Journal of Applied Linguistics, 161*(1), 90-110. https://doi.org/10.1075/itl.161.06unt

Volchenkova, K. N., & Bryan, A. P.. (2019). The influence of English medium instruction on teacher identity. *Educational Sciences, 11*(2), 68-78. https://doi.org/10.14529/ped190207

Yassin, S. M., Tek, O. E., Alimon, H., Baharom, S., & Ying, L. Y. (2010). Teaching science through English: Engaging pupils cognitively. *International CLIL Research Journal, 1*(3), 46-59.

Ying, Z. (2022). The application of CLIL approach in EFL writing course integrated with ideological and political elements. *Journal of Advances in Education and Philosophy, 6*(12), 568-572. https://doi.org/10.36348/jaep.2022.v06i12.002

Appendix 1

Students' English Proficiency and Perceptions of CLIL Lessons

Instructions: Please indicate your level of agreement with the following statements regarding your English language competence. Please answer according to your personal beliefs and learning experiences. You may put (✓) in the box for your answer.

1 = never or almost never true of me
2 = usually not true of me
3 = somewhat true of me
4 = usually true of me
5 = always or almost always true of me

Items	Level				
	1	2	3	4	5
In general, I can listen, speak, read and write in English effectively.					
I can listen and understand key information in English.					
I can speak English fluently and confidently.					
I can read and understand texts in English effectively.					
I can write grammatically correct sentences in English.					
I can read and understand research articles written in English.					
I can use academic vocabulary appropriately.					
I have knowledge of rhetorical structure in academic articles written in English.					
I can read and understand research abstracts written in English.					
I can write research abstracts that meet international standards in English.					

Appendix 2

CLIL Instructional Materials for the Abstract

Sample sentences corresponding to moves (text segments)

Background

5 hydroxylmethylfurfural (HMF) *is* a bio based chemical that can be prepared from natural abundant glucose by using combined Brønsted–Lewis acid catalysts

Purpose

In this work, Al3+ catalytic site *has been grafted* on Brønsted metal–organic frameworks (MOFs) to enhance Brønsted–Lewis acidity of MOF catalysts for a one pot glucose to HMF transformation.

Methods

The initial stage of glycerol conversion over H-ZSM-5 zeolite has been investigated *using density functional theory (DFT) calculations on an embedded cluster model consisting of 128 tetrahedrally coordinated atoms*.

Results

The *results* confirm that the method that takes weak interactions, especially the van der Waals interaction, into account is essential for describing the confinement effect from the zeolite framework. The effects of the infinite zeolitic framework on the cluster model are also included by a set of point charges generated by the embedded ONIOM model. The energies for the adsorption of ethene, benzene, ethylbenzene, and pyridine on H-ZSM-5 from an embedded ONIOM(MP2:M06-2X) calculation are predicted to be -14.0, -19.8, -24.7, and -48.4 kcal/mol, respectively, which are very close to available *experimental observations*.

Discussion

The confinement effect of the extended zeolite framework *has been clearly demonstrated* not only to stabilize the adsorption complexes but also to improve their corresponding activation energies to approach the experimental benchmark

Grammatical features :present tense, past tense, present perfect tense
Lexical features – nouns: challenge, significance, importance, potential, research, interest, effect, technique, observation, framework, model, method, finding
Lexical features - verbs: become, increase, graft, observe, analyse, investigate, demonstrate
Lexical features - adjectives :significant, important, crucial, major, great

A Sample Activity of the Abstract

A large proportion of the world's population lives in remote rural areas that are geographically isolated and sparsely populated. The present study is based on modeling, computer simulation and optimization of hybrid power generation system in the rural area in Muqdadiyah district of Diyala state, Iraq. Two renewable resources, namely, solar photovoltaic (PV) and wind turbine (WT) are considered. The HOMER software is used to study and design the proposed hybrid energy system model. Based on simulation results, it has been found that renewable energy sources perhaps replace the conventional energy sources and would be a feasible solution for the generation of electric power at remote locations with a reasonable investment. The hybrid power system solution to electrify the selected area resulted in a least-cost combination of the hybrid power system that can meet the demand in a dependable manner at a cost about $0.321/kWh. If the wind resources in the study area at the lower stage, it's not economically viable for a wind turbine to generate the electricity.

Move type identification task

Direction: Read the following abstract and identify the function of each text segment as B= Background, P = Purpose, M = Methods, R = Results, or D = Discussion. Write your answer in the space provides.

Adapted from: Hassan, Q. et al. (2016). Optimization of PV/WIND/DIESEL hybrid power system in HOMER for rural electrificat on. *Journal of Physics, 745*, 1-8.