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Challenges and Strategies on the Content and Language Integrated Learning Approach (CLIL): A Case Study from the Turkish Context

Retos y estrategias del enfoque de aprendizaje integrado de contenidos y lenguas extranjeras (AICLE): un estudio de caso del contexto turco

Desafios e estratégias da Aprendizagem Integrada de Conteúdos e de Língua (AICL): estudo de caso do contexto turco

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ABSTRACT. Limited studies investigate the high school teachers' challenges and strategies while teaching science and mathematics in English as the target language through the content and language integrated learning (CLIL) approach. Hence, this study aimed to investigate the challenges that science and math teachers encounter and the strategies they employ while fostering students' development of proficiency in English as the target language in physics, chemistry, biology, and mathematics courses in the International General Certificate of Secondary Education (IGCSE) and International Baccalaureate Diploma Program (IBDP). The study utilized various qualitative tools such as semi-structured interviews, open-ended questionnaires, and lesson observations to analyze science and math teachers' strategies and challenges at a case school in eastern Turkey. The study revealed that as part of the CLIL approach, the participant teachers indicated various challenges such as a lack of vocabulary repertoire, translation problems, and weak foundational knowledge. They used common strategies such as group work interactions, interdisciplinary activities, individualized feedback, the promotion of higher-order thinking skills, inquiry-based learning, and reinforcement of language used to deal with these challenges. The study presents further implications for good practices and recommendations to resolve challenges.

Keywords (Source: Unesco Thesaurus): Bilingualism; content and language integrated learning; English as a foreign language; language acquisition; science and math education in the target language.

RESUMEN. Muy pocos estudios investigan los desafíos y las estrategias de los docentes de secundaria al enseñar ciencias y matemáticas en inglés como idioma meta a través del enfoque de aprendizaje integrado de contenidos y lenguas extranjeras (AICLE). Por lo tanto, este estudio tuvo como objetivo investigar los desafíos que enfrentan los docentes de ciencias y matemáticas y las estrategias que emplean para fomentar el desarrollo de la competencia en inglés de los estudiantes como lengua meta en los cursos de física, química, biología y matemáticas en el Certificado General Internacional de Educación Secundaria y el Programa de Diploma de Bachillerato Internacional. Se utilizaron varias herramientas cualitativas tales como entrevistas semiestructuradas, cuestionarios abiertos y observaciones de clase para analizar las estrategias y los desafíos de los docentes de ciencias y matemáticas en una escuela de caso ubicada en el este de Turquía. El estudio reveló que, como parte del enfoque AICLE, los profesores participantes indicaron varios desafíos, incluidos la falta de repertorio de vocabulario, los problemas de traducción y unos conocimientos básicos débiles. Además, usaron varias estrategias comunes para enfrentar estos desafíos; por ejemplo, las interacciones de trabajo en grupo, las actividades interdisciplinarias, la retroalimentación individualizada, la promoción de habilidades de pensamiento de orden superior, el aprendizaje basado en la investigación y el refuerzo del lenguaje utilizado. Por último, se presentan las implicaciones adicionales para las buenas prácticas, así como algunas recomendaciones, para superar los desafíos.

Palabras clave (Fuente: Tesauro de la Unesco): Bilingüismo; Aprendizaje Integrado de Contenidos y Lenguas Extranjeras; inglés como lengua extranjera; adquisición del lenguaje; educación científica y matemática en el idioma meta.

RESUMO. Muitos poucos estudos pesquisam sobre os desafios e estratégias dos docentes do ensino médio ao ensinar ciências e matemática em inglês como idioma-alvo por meio da abordagem de Aprendizagem Integrada de Conteúdos e de Língua (AICL). Portanto, este estudo teve como objetivo pesquisar os desafios que os docentes de ciências e matemática enfrentam e as estratégias que utilizam para promover o desenvolvimento da competência em inglês dos estudantes como língua-alvo nas disciplinas de física, química, biologia e matemática no Certificado-Geral Internacional de Ensino Médio e no Programa de Diploma de Ensino Médio Internacional (International Baccalaureate). Foram utilizadas várias ferramentas qualitativas, como entrevistas semiestruturadas, questionários abertos e observações de sala de aula para analisar as estratégias e desafios dos docentes de ciências e matemática numa escola de caso localizada no leste da Turquia. O estudo revelou que, como parte da abordagem AICL, os professores participantes indicaram vários desafios, incluídos a falta de repertório lexical, os problemas de tradução e conhecimentos básicos fracos. Além disso, usaram várias estratégias comuns para enfrentar esses desafios, por exemplo: interações de trabalho em grupo, atividades interdisciplinares, feedback individualizado, promoção de capacidades de pensamento de ordem superior, aprendizagem baseada na pesquisa e reforço da língua utilizada. Por último, foram apresentadas as repercussões adicionais para as boas práticas, assim como algumas recomendações, a fim de superar os desafios.

Palavras-chave (Fonte: tesauro da Unesco): Bilinguismo; Aprendizagem Integrada de Conteúdos e de Língua; inglês como língua estrangeira; aquisição da língua; educação científica e matemática na língua-alvo.

Introduction

Prior studies on Content and Language Integrated Learning (CLIL) focused more on the growing interest in studying science and mathematics in English among bilingual students (Lueg & Lueg, 2015; Sawir, 2005) or the relationship between English language ability and academic achievement in science and mathematics (Abedi & Lord, 2001). Besides, many studies were conducted on CLIL at the primary, secondary, and tertiary levels in different contexts from all around the world, such as Colombia (Rodriguez Bonces, 2012), Saudi Arabia (Hashmi, 2019), Spain (Bellés-Calvera, 2018; Moore & Lorenzo, 2015), Russia (Rubtcova & Kaisarova, 2016), and Brazil (Siqueira et al., 2018), but no studies have yet been carried out on CLIL in the Turkish high school context.

Therefore, since there are limited studies on teachers' challenges and strategies of teaching science and mathematics in English as the target language with the CLIL approach in the Turkish high school context, this current research aims to investigate the challenges encountered and the strategies used by science (physics, chemistry, biology) and math teachers in fostering the development of proficiency in English and academic content in sciences and mathematics as part of the International General Certificate of Secondary Education (IGCSE) and International Baccalaureate Diploma Program (IBDP).

The study was based on the following research questions:

1) What challenges do science and math teachers encounter in their content and language instruction for non-native English-speaking high school students in IGCSE and IBDP science and math courses?
2) Which strategies do science and math teachers apply to content and language instruction for non-native English-speaking high school students in IGCSE and IBDP science and math courses?

Literature review

Challenges in CLIL

The main challenges from prior studies in the literature focused on a lack of authentic and personalized materials; insufficient professional development training; a lack of teacher expertise; logistical problems such as budget, timetable, and resources; the absence of a methodology or pedagogy on scaffolding; teachers' linguistic competencies; and a lack of collaboration or coordination between language and subject teachers. Although it varies from one context to another, these main challenges remain mostly the same in different educational contexts worldwide. The following research findings from different contexts illustrate these challenges unique to their environment, but they may also be observed in other educational contexts.

Some challenges arise due to the lack of preservice programs, professional development (PD), or training for effective implementation of CLIL. For example, in the South American context, Siqueira et al. (2018) explored challenges in CLIL implementation and revealed university courses and programs that do not usually prepare teachers to speak and teach foreign languages, having a shortage of preservice programs to prepare teachers for CLIL contexts. Charunsri (2019) also emphasized that in the Thailand tertiary education context, language teachers are not trained for specific-subject teaching, and vice versa, content teachers are not trained to teach language. In turn, teachers may see themselves as content or language teachers (Banegas, 2012). Therefore, "a strong collaboration among subject teachers and language teachers" (Biçaku, as cited in McDougald, 2016) is essential.

Other challenges may arise due to the lack of methodological and logistical support systems. For instance, in the Serbian context, Lazarević (2019) found that the implementation of CLIL was problematic because of the lack of structured and systematic support, insufficient teaching materials, and the unawareness of scaffolding students' language. Similar issues were also observed in the Finnish primary education context. Roiha (2014) examined teachers' perceptions, practices, and challenges on differentiation in CLIL and revealed various challenges such as the lack of time and resources, the materials, and the large class sizes. Furthermore, in the Colombian context, Torres-Rincón and Cuesta-Medina's (2019) exploratory qualitative study also revealed scarce staged lesson planning and teachers' lack of CLIL methodology. Some teachers misunderstand the CLIL concept, which leads them to think that they can implement CLIL simply by switching the language of that content into their target language (Pavón-Vázquez &

Rubio, 2013). Hence, to resolve these challenges, teachers need more resources, further professional training, and enhanced coordination to improve the quality of education through CLIL (Campillo et al., 2019).

Strategies for CLIL

Previous research revealed various self-reported pedagogical and actual teaching practices from the empirical studies. To start with the self-reported pedagogical practices, Coonan (2007) examined the self-reported pedagogical practices of teachers of history, math, natural sciences, geography, philosophy, and economics in the Italian secondary school context. Teachers reported teaching strategies such as conducting learning as a form of problem-solving; frequently using examples from everyday life; calibrating tasks according to students' competence levels; non-verbal strategies such as information organization in flowcharts; or interpersonal strategies such as promoting interaction between students to exchange ideas through pair-group work and in some cases cooperative learning, peer teaching, and peer help.

The empirical studies reflected teachers' actual practices in various educational contexts. For example, in primary education, Alcaraz-Mármol (2018) observed the CLIL methodology and revealed that trained teachers used materials other than textbooks, such as videos and CDs. As for activities and materials developed in the CLIL context, the research findings also revealed that controlled activities are more widely used than semi-controlled or free production activities. Among controlled activities were multiple-choice, matching, and gap-filling activities; the semi-controlled activities included drawing while following instructions, oral presentation, short writing with the help of clues, and oral debate. In secondary school, Villabona and Cenoz (2021) revealed that CLIL classrooms include a variety of input resources through audiovisual materials or texts in different forms and group work mostly on various tasks.

CLIL in mathematics and sciences

Previous studies examined the relationship between English language ability and academic achievement, especially in science and mathematics, and indicated that the students who were proficient English users performed significantly better in sciences and math than the students who were less proficient in English (Abedi & Lord, 2001, Ouazizi, 2016; Surmont et al., 2016). However, other studies also suggested that students who study science in their first language perform slightly better than their CLIL counterparts in the content subject (Fernández-Sanjurjo et al., 2017, as cited in Mahan et al., 2021). Meanwhile, CLIL science students vastly improve their reading, writing, and grammar compared to non-CLIL science students (Pérez-Vidal & Roquet 2015, as cited in Mahan et al., 2021). Although students may have a solid scientific and mathematical background, they may struggle to understand the content in the target language and fail to make an in-depth analysis of science and math subjects due to their lack of confidence in understanding the content (Sawir, 2005).

Methods

Research context

The context of this study is a co-educational private high school located in eastern Turkey. The case school implements international education programs for students in the region. The school was established in 2007 to provide students with the opportunity to experience high-quality education with international norms and standards. The main aim of establishing an academically challenging school was to improve eastern Turkey's educational opportunities for gifted and talented students. The school is the first and only school that offers two international programs (IGCSE and IBDP) and the Ministry of Education National Program (MoNEP) in the region. As school by-laws require, students at the case-study school must successfully pass the IGCSE and IBDP to receive a Turkish high school diploma. The school administers a rigorous entrance examination to admit the most academically talented students. The admitted student body consists of students who mainly come from state middle schools around the district.

Research design

The current study utilized a qualitative research method (thematic content analysis), including instrumentation such as semi-structured interviews, a questionnaire, and lesson observations with the science and math teachers at the case school. All these instruments were used for data triangulation purposes and to collect in-depth qualitative data on the phenomenon under investigation.

Research participants

At the time of the study, there were 12 science and math teachers at the case study school. These research participants were invited to participate in the questionnaire, semi-structured interviews, and online lesson observations (see Table 1). The entire population from the case school was asked to fill in the questionnaire. Six teachers from the case study school completed the questionnaire. As for the semi-structured interviews, a typical purposive sampling was used to determine the participants for the interviews. The sample was selected based on their years of teaching experiences at the case school and their program expertise in international programs. The interviews were conducted with four teachers from each subject (physics, chemistry, biology, and math) to collect data on the challenges and strategies for content and language instruction. Finally, as for the lesson observations, the researchers observed nine different teachers' online lessons in physics, chemistry, biology, and mathematics courses from grades 9 to 12 at the case study school.

Table 1. Research Participant Profile

Identification	Subject Area	Ethnicity	Data Collection Method	Grade Level & Program Observed
A	Physics	American	Semi-structured interview Lesson observation	Grade 10 / IGCSE
B	Biology	Turkish	Semi-structured interview Lesson observation Questionnaire	Grade 10 / IGCSE

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Identification	Subject Area	Ethnicity	Data Collection Method	Grade Level & Program Observed
C	Chemistry	Turkish	Semi-structured interview Lesson observation Questionnaire	Grade 12 / IBDP
D	Math	American	Semi-structured interview Lesson observation	Grade 9 / IGCSE
E	Physics	German	Lesson observation	Grade 12 / IBDP
F	Chemistry	Pakistani	Lesson observation Questionnaire	Grade 9 / IGCSE
G	Biology	Turkish	Lesson observation Questionnaire	Grade 9 / IGCSE
H	Math	Indian	Lesson observation	Grade 11 / IBDP
I	Math	Turkish	Lesson observation	Grade 12 / IBDP
J	Math	British	Questionnaire	N/A
K	Chemistry	Turkish	Questionnaire	N/A
L	Physics	Turkish	Questionnaire	N/A

Source: Own elaboration

Data collection

Necessary ethical considerations were followed during data collection to undertake this research, such as permission to do this research from the school administration, the university that governs the school, and the participants' consent. The data collection process for the questionnaire, semi-structured interviews, and lesson observations is outlined below.

Semi-structured interviews

The semi-structured interview was to collect data regarding the perceived challenges and strategies concerning the content and language instruction practices in physics, chemistry, biology, and math. Participants were invited with an informative email that provided detailed information about the purpose, the significance of the study, and interview questions in advance. The semi-structured interviews were conducted face to face in April 2019. The interview questions were prepared considering the stages of interview-based research (Brinkmann & Kvale, 2015). The interviews, which took around 40 minutes, were recorded with a recording device and transcribed for thematic coding and analysis.

Questionnaire

The questionnaire was administered to collect open-ended responses of the physics, chemistry, biology, and math teachers' strategies and challenges in content and language instruction practices. The questionnaire was an online Google form questionnaire that the research authors developed. The questionnaire design was based on the authors' research on the existing literature concerning CLIL. The questionnaire included open-ended questions for the participants to respond to in short written form. The research participants completed each part of the online questionnaire, as each item in the questionnaire was mandatory. The questionnaire results were collected from the physics, chemistry, biology, and mathematics teachers via an electronic email at the case school in February 2020.

Lesson observations

Lesson observations were conducted to collect further qualitative field notes about how the CLIL instructional approach was implemented in the science and math courses at the case school in December 2020. The lesson observation protocol was based on an observation tool developed by de Graaff et al. (2007) for evaluating an effective second language pedagogy in CLIL. The current study's researchers observed nine lessons in the physics, chemistry, biology, and mathematics courses. Due to the current COVID-19 pandemic worldwide, during the lesson observations, the Turkish Ministry of National Education (MoNE) required all state and private schools to implement virtual education to prevent the spread of coronavirus at schools. Therefore, the researchers conducted their lesson observations online as teachers

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taught their lessons remotely through the Zoom platform. The researchers kept running field notes in each 60-minute class using the observation instrument indicators for CLIL pedagogy. The researchers recorded each lesson in the lesson observation form and analyzed it qualitatively according to the performance indicators.

Data analysis

The researchers focused on the qualitative findings concerning the strategies employed and challenges encountered while teaching content knowledge to students in English as the target language in their data analysis. Specifically, the researchers used thematic content analysis (Creswell, 2007), where they looked at the emerging themes out of the open-ended responses from the questionnaire, the transcription of semi-structured interviews, and the field notes of lesson observations.

Results

Research question 1: What challenges do science and math teachers encounter in their content and language instruction for non-native English-speaking high school students in IGCSE and IBDP science and math courses?

Lack of vocabulary repertoire

One of the foremost common challenges repeated in the semi-structured interviews and questionnaire was that students struggle to understand the critical ideas due to their lack of vocabulary. Some teachers reported that essential vocabulary plays a vital role in deeply understanding mathematical and scientific concepts. For example, the physics teacher (A) stated in the semi-structured interview that once students are confident in the language of instruction, they can quickly process the information provided. The biology teacher (B) pointed out in the questionnaire that students have difficulty understanding the question in assessment because of an unknown or misinterpreted word in the target language. She adds, *"it may be difficult to understand the answers of these students, especially in questions requiring interpretation skills, during the exam."* Teacher (B) also pointed out that when students use the daily language (unscientific) terms as they paraphrase in their assessments, they lose points based on the mark scheme or internal assessment criteria.

Translation problem

Several interview participants reported that translating the content knowledge from the first language to the target language disrupts knowledge. Specifically, the biology teacher (G) said that when students do not feel strong enough in English in the first years of high school, they prefer memorizing facts and answering questions with the help of memorizing material. Because of the memorization method, they encounter problems such as the inability to provide a fully comprehensive answer to questions. Another problem is that even if students know the answer to the questions, they cannot put them into writing correctly. The physics teacher (A) reported in the semi-structured interview that many students confessed that although they know the answer to the question, they cannot answer it right away in English. They think about the question in their first language and then translate it into English. He believes that until English becomes almost equal to the first language, the translation from the first to the second language is inevitable.

Similarly, in the semi-structured interview, the chemistry teacher (C) emphasized the importance of thinking in the language of instruction. He stated, *"when students think in Turkish and try to translate it into English, they can lose substantial amounts of information in the process."* Teacher (C) also pointed out in the questionnaire students' tendency to think in Turkish rather than the target language. Similarly, in the questionnaire, the physics teacher (L) pointed out the problem with students' translation approach during their assessments, which leads them to lower performance in their examinations. *"Students have difficulties understanding content in the exam questions, they usually try to translate in their minds, and they have difficulties differentiating command terms."* He also mentioned that some students hesitate to ask their questions in the target language as they are afraid to make language mistakes, so they prefer to use Turkish, but then *"when the teacher insists on speaking in English, they tend to stop even asking questions in their mind."*

Weak foundational knowledge

Another reported challenge was the weak foundational knowledge in science and mathematics. Students in the lower grades who are newly exposed to English encounter difficulties understanding scientific concepts in English. When they do not have a deeper understanding of concepts, they lose their motivation to learn science or math. For example, the math teacher (J) stated in the questionnaire that students with a weak foundation in math are unable to grasp the more complex topics in English. Thus, it takes much time after school to provide them remedial classes so that they meet the expectations of the IGCSE and the IBDP at the school. Nevertheless, the math teacher (D) stated in the semi-structured interview that students who have difficulties in spoken and written English can still function well in the math classes in the target language because *"in mathematics a question that would ask a student 'to explain...' they would show it mathematically and not in word form."* Even though participant teachers reported that students have difficulty understanding the concepts due to weak English capabilities, the researchers did not observe in any lessons that teachers adapted their language after realizing that the language they use is beyond students' level. Other than the weak foundational knowledge in science and mathematics, students with weaker language abilities tend to stay quiet in class rather than engage in active inquiry-based active participation. To illustrate, the physics teacher (A) reported in the questionnaire that *"it is very difficult to start a conversation with students who have difficulties in English. If students don't ask for clarification when they are in doubt, then they aren't able to gain a deep understanding of scientific concepts."* There needs to be "student-student" and "teacher-student" interaction for teachers to understand to what extent students understood the topic of the class.

Research question 2: Which strategies do science and math teachers apply to content and language instruction for non-native

English-speaking high school students in IGCSE and IBDP science and math courses?

Pair and group work interactions

Group work interactions are one of the strategies teachers employ to promote language learning in their classes. The teacher (D) in the semi-structured interview reported that he often uses group work interactions in class when they are solving problems. He asks students to discuss the possible creative solutions to the problems in groups. Group work interaction is also observed during the lesson observations in the grade 10 IGCSE biology lesson; after watching a video on "the mold story," the biology teacher (B) asks students to work in groups to discuss the advantages and disadvantages of asexual reproduction as well as sexual reproduction to a population of a species in the wild and to crop production. Students discuss their tasks in the target language in the breakout session on the distance learning platform (Zoom), take notes as they discuss, and finally report their ideas to the class. It was also evident in the grade 10 IGCSE physics and grade 9 chemistry lessons. The teacher (A) asks students in pairs to describe how the scattering of a-particles by thin metal foils provides evidence for the nuclear atom to encourage them to talk to each other in the target language. In the IGCSE grade 9 chemistry lesson, the teacher (F) asks students to work in groups in the breakout sessions on Zoom and cooperate to do the exercises on "mole" in the target language. Even though group work has been identified as one of the effective strategies when teaching science and mathematics through the CLIL approach in the semi-structured interviews and lesson observations, none of the participants reported this in the questionnaire.

Interdisciplinary activities

Teachers reported that interdisciplinary activities are good ways to promote language learning in science and mathematics lessons. In chemistry, the teacher (K) pointed out in the questionnaire that students get engaged in practicing the target language during the interdisciplinary and integrated group activities. He stated that he tells his students to

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keep a notebook of the new words they learn as they use them in sentences, both in writing and orally. They develop their scientific vocabulary in the target language. The vocabulary that they register in their books may help students in different subject areas that they study. In this way, they can also make interdisciplinary connections easier.

Similarly, in biology, the teacher (B) reported in the semi-structured interview that many students have difficulties in science courses. As students read the content without understanding, especially in the lower grades, she stated that she would provide students with a variety of reading materials containing scientific vocabulary that help them familiarize themselves with the scientific concepts and practice understanding the material they read. They may also come across vocabularies that help them make interdisciplinary connections. The semi-structured interviews and questionnaire reported interdisciplinary activities as a strategy to promote CLIL in the classroom but were not observed during the online lesson observations.

Individualized feedback

Another important strategy employed by teachers was providing individualized feedback to students to develop their linguistic skills. The mathematics teacher (D) stated in the semi-structured interview that providing individual support can be highly effective for students struggling to grasp the concepts in the target language. He also reported that providing written explanations helps students grasp the knowledge more efficiently. The biology teacher (G) makes a similar contribution in the questionnaire that the written feedback given about students' language use mistakes in their quizzes, homework, or exams is also constructive for students to improve their spelling and grammar in the target language.

Individual feedback was also evident in the online lesson observations that the researchers conducted. For example, in the grade 10 IGCSE biology lesson, the teacher (B) asks students to watch a video about asexual and sexual reproduction and then asks them to define asexual reproduction as a process resulting in the production of genetically identical offspring from one parent and define sexual reproduction as a process involving the fusion of the nuclei of two gametes.

Students send their definitions to the teacher through the chat box. The teacher quickly checks and gives them feedback about their answers, explicitly focusing on the accuracy of their spellings and meanings of the keywords. In chemistry, the teacher (C) checks whether students have understood the most crucial concept of the lesson, namely "isomerism," by asking students to define this concept. Then, the teacher paraphrases the student's words and writes the concept's definition. He also asks students to differentiate the concepts among "cis-trans isomers, optical isomers, and conformational isomers." The teacher nominates some students randomly to answer his question and then paraphrases students' answers and gives feedback about the accuracy of their answers. In physics, the teacher (A) asks students to describe the structure of an atom in terms of a positive nucleus and negative electrons in the grade 10 physics lesson. To help students identify the meaning of the critical concepts, the teacher asks them to describe them through a visual diagram. The teacher gives feedback to students about how they use the term "proton number *Z*," the term "nucleon number *A*," and the term "nuclide and the nuclide notation." Providing individualized or group feedback was evident in the semi-structured interviews, questionnaires, and lesson observations.

Higher-order thinking skills and inquiry-based learning

The promotion of higher-order thinking skills and inquiry-based learning was reported as strategies teachers use in their classrooms to promote language skills and different interaction patterns. Students stimulate higher-order thinking skills by using the target language effectively in all four linguistic skills, reading, writing, speaking, or listening when they study science and mathematics subjects. The chemistry and physics teachers reported in the questionnaire or semi-structured interviews some similar ways for fostering students' higher-order thinking skills by facilitating the lesson in a way that would allow students to comprehend the given information and extrapolate results. The chemistry teacher (F) stated in the questionnaire that he distributes detailed presentations to students before his lessons so that they have something written in their hands and focus on the lesson objectives they will cover. Similarly, teacher (A) in his IGCSE physics classes

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reported during the semi-structured interview that he would give students the main ideas and the critical terminology about these main ideas. He would ask them to focus on these main ideas and terminology so that students can refine and correlate the essential terminology to the lesson's main concepts. As for the inquiry-based instruction to promote language and content integrated instruction, the mathematics teacher (D) reported in the semi-structured interview that he often uses inquiry-based discussions in class when solving problems. He asks students to discuss the possible creative solutions to the problems in groups.

Furthermore, critical thinking, as an essential aspect of higher-order thinking skills, has also been used as a strategy in the online lessons observed. For example, in the grade 11 IBDP math lesson, teacher (H) explicitly references critical thinking and tells students, *"The seemingly abstract concept of calculus allows us to create mathematical models that permit human facts such as getting a man on the moon."* Then the teacher asks them to answer the following question: *"What does this tell us about the links between mathematical models and reality?"* Besides, in the grade 12 IBDP math lesson, teacher (I) teaches the differential equations as part of the Maclaurin Series topic. As he teaches this topic, he explicitly references how we know what we know. He asks his students the following questions for developing students' critical thinking skills: *"Is there always a trade-off between accuracy and simplicity?" "Thinking the data we have about a particular function and modeling it, to what extent can we be sure about the accuracy of our knowledge?" "What does it mean to say that mathematics is an axiomatic system?"* The teacher expects students to practice the target language outside of problem-solving exercises to provide examples of language forms and structures that are also relevant in other contexts. As exemplified, the promotion of higher-order thinking skills through effective use of linguistic skills was reported in the semi-structured interviews, questionnaire, and lesson observations.

Reinforcement of language use

The participant teachers emphasized the importance of possessing a rich vocabulary repertoire and solid grammar knowledge for students to use higher-order thinking skills and express themselves effectively in the target language. For example, teacher (B) explained in the questionnaire that *"the nature of the subject requires higher-order thinking skills, and they need to make good use of grammar and vocabulary (both subject-specific and general) to express their ideas or knowledge correctly."* Teacher (K) also touches upon the importance of always using the target language and being a role model for ensuring that students use correct grammar, spelling, and pronunciation in the target language. The physics teacher (A) makes a similar contribution in the semi-structured interview and emphasizes the importance of content reading in physics. He pointed out that the language of physics is mathematics, and students need to know mathematical notations. When students need to answer a question, they need to know the mathematical notations and use the scientific terminology appropriately. Some students think they need to write in physics classes as they do in a creative writing classroom. He helps them think about physics in English and then write it with the correct terminology.

The emphasis on students' lexical repertory was also evident in the researchers' lesson observations. The teachers attempted various strategies to promote vocabulary learning in the classroom. For instance, in the grade 12 IBDP physics lesson, teacher (E) asks students to match meanings and definitions of concepts of nuclear reactions, conservation laws, unified atomic mass, mass-energy equivalence, mass defect, and binding energy as well as binding energy per nucleon. The teacher shares random definitions on the screen and asks students to match the concepts given before the activity. The teacher gives students three minutes to complete a task. After three minutes, everyone shares their answers with the whole class. Also, in the grade 11 IBDP math lesson, the teacher (H) asks individual students to describe what bisection and intersection mean and their differences. The teacher ensures that an individual student answers his question repeatedly through the random student nomination technique. In the grade 12 IBDP chemistry lesson, the teacher (C) asked students to watch a video about the side effects of the optical isomers and note down how the medicine "Thalidomide" influenced pregnant women negatively. From time to time, the teacher stops the video to help students understand the problematic unknown words such as "malformation of limbs," "blood clots," and "peripheral neuropathy." In the grade 9 IGCSE chemistry lesson, the teacher (F) does a true or false exercise with thumbs up or down on the concept of mole for checking students' comprehension and then continues with exercises on "mole calculations by ratio" for which students work individually and solve the questions on their own and report their answers in the chat room. In the same lesson, the teacher (F) also asks students to log into the "Socratic" learning platform and do the exit ticket to reflect on their learning outcomes. When students do not understand some of the questions, the teacher helps students to understand the meaning by paraphrasing the questions. Many participant teachers reported through the questionnaire, semi-structured interviews, and lesson observations that they use vocabulary-building strategies in their classroom for CLIL.

The participant teachers also emphasized the importance of being exposed to the target language spoken by the native English speakers. The teachers (F and G) highlighted how students could develop their pronunciation while watching videos or animations vocalized by native speakers of English, which helps students in different ways, such as the correct pronunciation of the words as well as assisting the students to hear the proper grammatical structure while watching the videos. One of the chemistry teachers (K) reported in the questionnaire that it is imperative for teachers always to use the target language so that students are imposed on the correct use of terminology, allowing them to grasp the terminology and correct grammatical usage. The teachers (A, C, D, and G) also indicated that speaking slowly and repeating the same concept while teaching important and complicated mathematical and scientific concepts may be helpful for non-native English-speaking students. These teachers tried exposing students to the target language by showing them videos related to class objectives, using the target language consistently during class time, and ensuring that all students always use it. There were examples of the same strategy in the lesson observations. In the grade 12 IBDP math lesson, the teacher (I) asks students to do a reflection assignment on specific questions regarding "accuracy, efficiency, and simplicity" to practice the target language with the help of mathematical discussions. In the grade 12 IBDP chemistry lesson, the teacher (C) asks some students questions about the CIP model, and then to encourage other students to react to each other's reactions, he says, *"Let me check what others think?"* In the grade 10 IGCSE biology lesson, before the class watches the video to meet the objective, the biology teacher (B) explains what "budding" is by giving a translation, then explains what "meiosis" is with the help of visual aid.

Furthermore, some teachers (C and G) emphasized the importance of writing activities as a strategy when learning the content in the target language. While the biology teacher (G) stressed in the questionnaire the importance of making summaries to understand the topic and practice using the target language in biology, the chemistry teacher (C) reported explicitly in the semi-structured interview that it is vital to answer questions in a way that they systematically express their ideas in the chemistry classes. Therefore, the teacher (C) assigns homework that requires students to answer open-ended questions as it helps them to improve their scientific writing skills. The teacher (G) continued pointing out the importance of key terms and how they are used in sentences and explained that *"When pure knowledge is given, students use present tense, but when they represent their findings in the internal assessment reports or extended essay, they need to use passive tense. Even in speech or reports, I try to do my best to correct their mistakes and give advice on using grammar check in Word or software such as Grammarly*. Although an emphasis on the writing activities was evident in the semi-structured interviews and the questionnaire, the researchers did not observe it as one of the strategies teachers used while teaching their subject area in the online lessons.

Discussion

The primary purpose of this study was to make an in-depth qualitative analysis of the science and math teachers' challenges and strategies on CLIL in a specific case school that implements international programs. The researchers were engaged with qualitative methods such as semi-structured interviews, questionnaires, and lesson observation to triangulate the information for the challenges and strategies that science and mathematics teachers encounter or employ at the case school. In this section, the authors will present and discuss the common challenges and strategies and how some of these challenges can be further resolved.

To start with the everyday challenges, the science teachers reported both in the questionnaire and the semi-structured interviews that students who lack vocabulary struggle to gain a deep understanding of the scientific concepts, which prevents them from improving their knowledge of topics that require higher-order thinking skills. Similarly, the mathematics teachers think that even though students possess strong mathematical skills, they would struggle explaining concepts in word form and would instead feel more comfortable explaining the concepts in mathematical notations. It is also evident in the research conducted by Sawir (2005) that although students may have a solid scientific and mathematical background, they may struggle to understand the content in the target language and fail to make an in-depth analysis of science and math subjects due to their lack of confidence in understanding the content. Finally, the most common challenge students encounter in the CLIL classroom is that they think in their mother tongue and translate the information to the target language, which has not been extensively discussed in the literature.

The semi-structured interviews, open-ended questionnaire results, and lesson observations indicated various strategies teachers used in science and math courses as part of the international programs to resolve some of these challenges. Specifically, the biology teachers think that students need to use higher-order thinking skills to make sense of the scientific concepts that students are exposed to, especially in the higher grades in the IBDP. The mission of the International Baccalaureate Organization (IB) states that the IB programs aim to develop "inquiring, knowledgeable and caring young people who are internationally minded" (IB, 2008a, p. 3). Students studying in the IBDP are exposed to content for which they need to use their higher-order thinking skills through various assessment methods, enabling them to develop such skills and become academically equipped for tertiary education. Additionally, the chemistry teachers emphasized the importance of the vocabulary repertory for an in-depth grasp of the scientific concepts. In this sense, the CLIL classroom requires students to think in the target language, use correct grammar and vocabulary, and engage in discussions. While Dalton-Puffer (2011) claims that CLIL instruction positively affects language development, writing proficiency, and vocabulary knowledge, Admiraal et al. (2006) put forward that CLIL instruction does not significantly affect students' academic vocabulary usage.

Coyle (2007) also pointed out that students need to engage in the target language to serve their thinking process and develop their higher-order thinking skills in the target language, promoting high-quality learning in the CLIL context. Accordingly, the physics and mathematics teachers reported in the open-ended survey questions and semi-structured interviews that inquiry may be helpful for students to improve their thinking and linguistic skills. This finding is consistent with the research findings of Baker (2002), where thinking and inquiry have been reported as essential skills for facilitating cognitive development and correct language use of CLIL learners. Similarly, San Isidro (2018) also puts forward in his study the benefit of inquiry-based instruction, which engages students when grasping knowledge and essential skills through inquiry and deep discussions around the concept they are working on.

Moreover, the physics and mathematics teachers reported in the survey and semi-structured interviews that using interdisciplinary planning in physics and mathematics will be helpful for students to develop a better linguistic understanding in class. This finding is also consistent with the literature. Darn (2006) and Tennant (2002) emphasized the importance of interdisciplinary and cross-curricular teaching and how the philosophy behind CLIL provides students with meaningful ways to use the information learned in one discipline as a good foundation in another field. Such interdisciplinary or cross-curricular lessons require good planning. As Torres-Rincón and Cuesta-Medina (2019) suggest using a customizable CLIL lesson plan and developing a unified lesson plan for the science and mathematics teachers may help them promote language teaching while teaching science and mathematics content in their lessons. It may also help achieve standardized instructional content across science and mathematics departments.

The results also revealed the importance of student-teacher interactions in the target language. Teachers promoted interactions amongst students in the target language, as reported in the questionnaire and

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observed during online lessons. Several activities in the lesson observations provided opportunities for students to interact with each other in the target language and practice various linguistic skills in a teacher-supervised learning environment. The observed teachers used different methods for facilitating interaction, such as group work activities, vocalized video watching/content discussion, and text reading/content analysis. Teachers also reported in the questionnaire that student-teacher interactions and exposure to the target language could effectively promote language learning while learning science and mathematics content. As teachers interact with students in the target language, they use the subject-specific terminology, which potentially would positively affect students' use of the target language specific to science and mathematics knowledge areas. This finding was also reflected in the literature. Dalton-Puffer (2011) emphasized the importance of "student-centered learning" instead of "teacher-centered" practices in a CLIL classroom. Dalton-Puffer also elaborated on the active student involvement of students in the CLIL classroom, which allows students to have more room for active engagement in classroom discourse. Likewise, Alcaraz-Mármol (2018) also reported that engaging students with the target language using external resources such as audiovisual materials could also effectively promote content and language integrated learning. Lastly, various science and math teachers reported that providing individual help and personalized feedback on student works would be beneficial for students to improve the quality of their work, which will allow students to understand better the concepts taught individually and to go over the feedback given personally.

The analysis of the questionnaire results, semi-structured interviews, and lesson observations showed that the science and math teachers had developed the above strategies for dealing with these particular challenges. Looking at the issue from a broader perspective, the researchers can provide further recommendations that may offer some notable contributions to the phenomenon. Firstly, teachers teaching science and mathematics to students who are English as second language learners may be provided with workshops on teaching language strategies. In this way, they will better understand how students learn languages and to what extent they can help students develop their linguistic skills in addition to science and mathematics content knowledge. Secondly, science and mathematics teachers can have opportunities to share their experiences with other teachers. They may adopt these best practices in their classroom. Sharing ideas may inspire teachers to come up with new ideas and strategies. Besides, promoting collaboration and reflection among teachers may be an effective way to improve their classroom practices. Thirdly, to help teachers plan practical lessons for the CLIL classroom, a template for CLIL lessons can be developed, including linguistic objectives, content objectives, and activities and assessment practices for the content and language integrated learning. Teachers can also use the flipped classroom method to integrate various pre- and post-activities to increase student engagement and classroom participation.

In conclusion, the authors would like to present some limitations to the study and recommendations for future research on the CLIL approach. This study was limited to only one case school to collect in-depth qualitative data from the high school science and math teachers in IGCSE and IBDP contexts. Therefore, the authors recommend that future studies be conducted in multiple school contexts with larger sample size, including teachers' and students' challenges and strategies on the CLIL approach. Besides, since this study was limited to exploring the phenomenon only qualitatively, the authors recommend that future studies focus on mixed methods to capture enriched data in various subject areas and international education programs. Finally, lesson observations have been conducted virtually due to COVID-19. Due to the nature of the online learning environment, observations might differ from face-to-face occurrences.

On the other hand, it should be noted that the observations of virtual lessons could also add some value to the empirical research studies, as it provides various examples of how CLIL is actualized through virtual education. Overall, the authors recommend that educational policymakers take more comprehensive action to achieve a broader objective and disseminate the use of CLIL classroom practices. Educational institutions can be supported by developing a mechanism to expedite understanding of the philosophy behind CLIL. Educational content developers can create authentic materials that would cater to the needs of teachers teaching in a CLIL environment.

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