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CLIL in Mathematics: An experiment in developing mathematical literacy in secondary education in Turkey

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Abstract

As reported by the Organisation for Economic Co-operation and Development (OECD), a mathematically literate student can recognise the role that mathematics plays in making well-founded judgments and decisions needed by constructive, engaged and reflective citizens. This case study aims to elucidate the steps that can be followed to develop mathematics literacy for bilingual education in Turkey which contributes to the COST Action CA21114-CLIL Network for Languages in Education: Towards bi- and multilingual disciplinary literacies (CLILNetLE), and discussions on how to integrate CLIL in mathematics education worldwide. In this study, ten mathematics questions in both English and Turkish were prepared by a mathematics teacher for 11th and 12th-grade students (n=38) whose native language was Turkish in a state secondary school. There were target words in mathematics questions in English that were identified through a needs analysis conducted on students, such as *tangent*, *circular*, *exponential*, *pendulum*, *stationary* and *constant*, which students reported as unknown English words and had to know in order to understand the questions in mathematics. Feedback was collected from experts in CLIL and students of CLIL application in mathematics. Sample data are provided, accompanied by photos to show how CLIL can be utilized to teach mathematics.

Keywords: CLIL in mathematics, mathematics literacy, CLIL implementation, secondary education

1. Introduction: An Overview of CLIL in Turkey

In the literature it is stated that CLIL in Turkey dates back to the 1950s in the Maarif Schools, and after starting negotiations with the European Union, an integrated curriculum in which the medium of instruction was a foreign language, namely English, began to be implemented (see Koç, Yuksel & Altun, 2021; Cetintas & Genc, 2001; Alper, 1995). Science and mathematics have been taught in a foreign language in addition to intensive language and literature teaching as a separate subject in these Maarif Schools. Recently, as a result of a decision by the Ministry of Education, these schools have operated under the name of Anatolian High Schools (Coşkun-Demirpolat, 2015).

As stated by Llinares and McCabe (2023), CLIL came to the fore in the mid-1990s with the goal of cultivating European citizens' competence in foreign/second/additional languages. Since the late 1990s, some private schools in Turkey have been using CLIL in primary and secondary education (Korbek, 2020). There are some studies on CLIL implementation in Turkey, and findings showed that technology integration in CLIL classrooms is still in its infancy (Koc et al., 2021) and there is a lack of pedagogical knowledge about how to integrate content and language (Gulsen & Dikilitas, 2023). Abdelaty (2023) discussed the pedagogical shift from the traditional methods of language teaching to groundbreaking strategies such as CLIL. Onder-Ozdemir (2023) used CLIL in medical English classes during COVID-19 as a coping strategy in higher education. Her findings revealed how students' motivation can be increased and critical thinking skills promoted in unexpected crises using CLIL.

In this study. CLIL was utilized as a methodology. CLIL methodology aims to equip students with both "language skills" and "content" acquisition at the same time (Coyle, 1999; Marsh, 2002). CLIL focuses on teaching a curricular subject, such as mathematics in this study, through the medium of a language other than that which is normally used, which is Turkish. It should be noted that "content" and "language" have different types of interpretations in the literature. In this study, following Coyle, Hood, and Marsh (2010), CLIL is defined as "a dual-focused educational approach in which an additional language

is used for the learning and teaching of both content and language" (p. 1) to achieve a specific level of mastery both in mathematics and English.

CLIL experiences have supported the idea that changing the language of instruction to a foreign language, such as English, can pave the way for a significant change in how students learn in primary and secondary education (Arnandiz et al., 2022). In a longitudinal study, Granados López-Jiménez and Lorenzo (2022) exemplified how formal bilingual education can boost lexical literacy in history writing. There are also suggestions for successful CLIL implementations, such as assessing students' additional language proficiency, providing help and support when needed (Ball et al., 2015) and activating prior knowledge (Bentley, 2007). Recently, the shift from the originally disciplinary-oriented instruction to social and cognitive factors has been extensively discussed by Jiang et al. (2023).

In multilingual contexts, it is important to take time to discuss methods used in different cultures represented by learners in the classroom to promote inclusivity and respect, encourage critical thinking and develop cultural competence, given that culturally responsive teaching adapts instructional materials to reflect the diversity of the classroom, making learning more relevant and effective. Coyle (2007) suggested the 4Cs of CLIL for planning successful lessons, which include social and cognitive factors that focus on the "interrelationship between content (subject matter), communication (language), cognition (learning and thinking) and culture (social awareness of self and 'otherness')" (p. 550), which were used as a guide in the present study:

1. Content (aligned with the curriculum): What is the mathematics topic? (e.g., trigonometry, functions, logarithm);

2. Communication: What language of mathematics will learners need to communicate during the lesson? (e.g., the language of trigonometric functions, formulas and theorems);

3. Cognition: What thinking skills are demanded of learners? e.g., identifying, classifying, reasoning, generalising;

4. Culture (sometimes the 4th C is referred to as Community or Citizenship): Do learners from different language backgrounds calculate in the same way? What symbols do they use?

2. The Language of Mathematics

Words and symbols are used in combination in mathematics. When the language of mathematics is examined, it is composed completely of assertions about mathematical objects. When we examine textual mathematics, we can see that mainly third-person singular and third-person plural are used to "denote individual mathematical objects (or propositions) and collections of mathematical objects (or propositions), respectively" (Ganesalingam, 2013, p.21). As Novotná and Hofmannová (2000, n.p.) have noted,

> Mathematics is a discipline where non-verbal communication, visual and graphic materials are used in a considerable extent. Its language has a typical grammatical structure and is rich in words that are only found in this specific field. The mathematical vocabulary is similar across many languages.

The interrelationship between language and content issues in mathematics is of considerable importance (Grabner et al., 2012). There is a critical relationship between mathematics and the language we use. Mathematical processes require a large amount of procedural knowledge, mainly related to language (Hiebert & Lefevert, 1987). Creating and using the mathematical language correctly is significant for the success of mathematics teaching (Toptaş, 2015). One of the basic steps in learning mathematical knowledge and transitioning to mathematical thinking is the correct use of mathematical language (Özdemir, 2014). Language use does not only mean that the student expresses the information he or she has acquired; it is also one of the basic elements in shaping thought (Schütz, 2002). Vocabulary makes a crucial contribution to overall understanding in many content areas, including mathematics. Another challenge can be the language and terminology of mathematics in English. For example, in daily life, the word "right" as an adjective has several meanings, such as being correct based on true information, being suitable, as a direction (right/left side) and human

rights. However, in mathematics, one of the uses of the word "right" is the meaning of "an angle of 90°, like the angles at the corners of a square," which is different from daily use. Effective methods for teaching vocabulary across all content areas are diverse and long-standing. Teaching and learning the language of mathematics is vital to the development of mathematical competence. Students' mathematical vocabulary learning is a very important part of their language development and, ultimately, their mathematical competence (Riccomini et al. 2015).

3. STUDIES ON CLIL IN MATHEMATICS

There are few studies on CLIL in mathematics. An investigation was performed by Cabezuelo and Pavón (2019) into the extent to which the use of L2 in maths tests influences bilingual education learners' process of word problem-solving in mandatory secondary education. Using action research, Šenkyříková (2023) investigated the implementation of CLIL in mathematics courses in the sales assistant programme in vocational schools in the Czech Republic for the assessment of the effectiveness of CLIL on students' understanding and proficiency in both language and mathematics. Data were collected using a pre-test and post-test. The findings showed significant improvements in vocational students' knowledge and comprehension. Systematic reports on the effects of mathematics CLIL instruction were analyzed in two studies at the secondary school level (Ouazizi, 2016; Petrášková, & Komínková, 2014). These studies showed that the students who received CLIL instruction performed better in the mathematics test than those with instruction in their mother tongue. In a mathematical test of quadratic equations used by Ouazizi (2016) for the measurement of students' mathematics knowledge, the CLIL and non-CLIL groups achieved relatively high scores, but the CLIL group's score was slightly higher. Using two mathematics didactic tests in English and the students' mother tongue, students' word problem-solving skills were assessed by Binterová et al. (2014). Their findings suggest that CLIL is more effective in enhancing students' language skills and problem-solving skills in mathematics.

4.PRESENT STUDY

There is little research that has investigated the steps in learners' and CLIL teachers' initial experience in mathematics education of both content and language integration, especially in developing countries like Turkey. A reason for this can be the challenges encountered when trying to implement CLIL such as:

- language proficiency of content teachers
- language proficiency of students
- the country's education policies
- mathematical language and terminology
- differences in mathematical notation and symbols in different languages

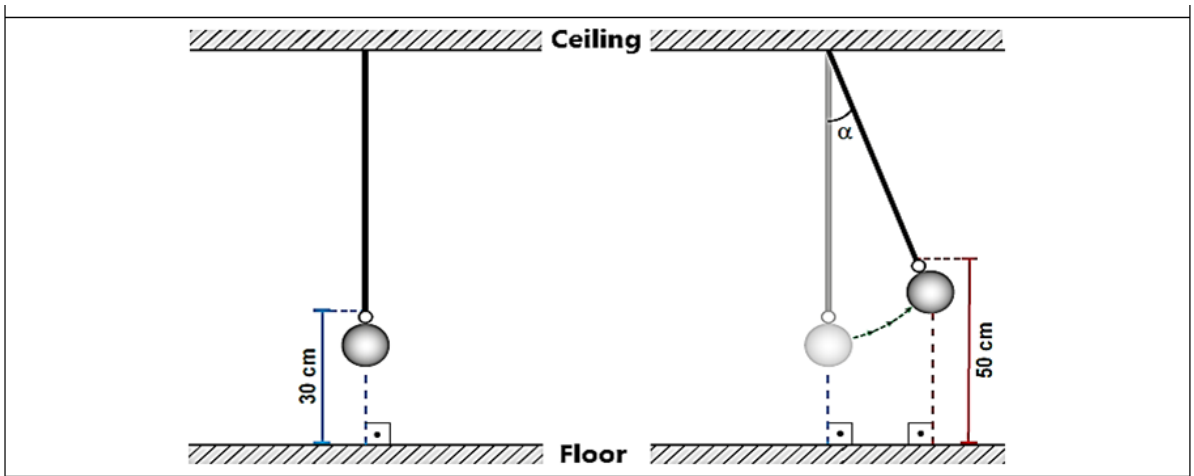
According to the 2018 Education First report, Turkey ranked 31st among 32 European countries and 73rd among 88 countries in the world. Thus, content teachers' and students' lack of English language skills can be one of the critical challenges when CLIL is used in Turkey.

Given the significance of mathematics and gaps in the literature, this study aims to elucidate CLIL application to mathematics classes in a state secondary school in Turkey. In this research context, learners gain knowledge of the curriculum subject in mathematics classes, while simultaneously learning and using English as a foreign language. It should be noted that content was the first objective, and that this curricular content led to objectives for English language learning. Thus the following steps were followed:

- Choosing trigonometry as the subject with students in grade 11.
- Identifying the questions from the mathematics textbook in Turkish.
- Translating the questions from Turkish into English.

In Figure 1, below, there is a mathematics question from the 11th-grade mathematics textbook in Turkish on the left side. To implement CLIL the question was translated into English. When we compare the same mathematics question in English

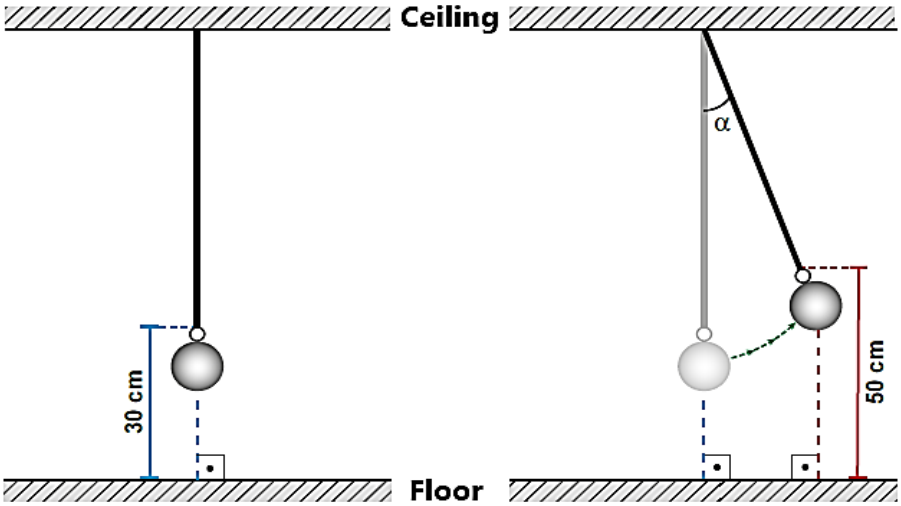
and Turkish, there are almost no similar words apart from the numbers. This illustrates one of the challenges.



Şekil I'de verilen sarkaç zeminden 200 cm yükseklikteki tavana bağlanmıştır. Sarkacın hareketsiz olduğu anda bağlı bulunduğu ipin ucu zeminden 30 cm yüksektedir. Sarkaç Şekil II'deki konuma geldiğinde ipin ucunun zeminden yüksekliği 50 cm ve ipin ilk konumuyla yaptığı açının ölçüsü α'dır.	The pendulum in Figure I is attached to the ceiling at the height of 200 cm from the floor. When the pendulum is stationary, the end of the rope is 30 cm above the ground. When the pendulum is in the position as shown in Figure II, the height of the end of the rope from the ground is 50 cm and the angle of the rope with its initial position is α.
Buna göre sin α değeri kaçtır?	**Accordingly, what is the value of sin α?**

Figure 1. Mathematics question in Turkish and English

Below are three sample mathematics questions from the textbook used in the classroom (see Figures 2, 3, 4).



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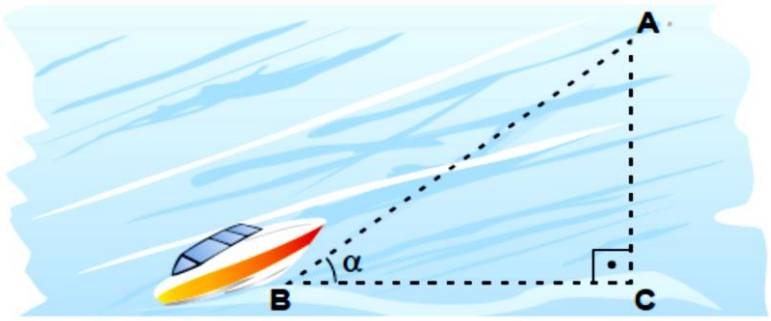
Accordingly, what is the value of sin α?

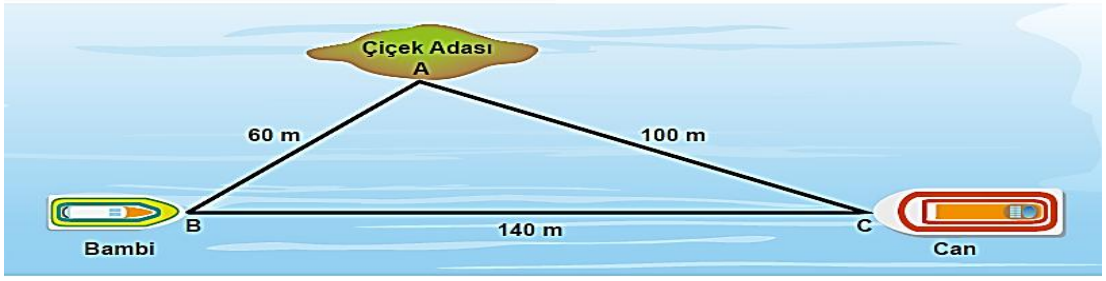
Figure 2. Sample question 1.



The motion of a boat is modeled in the Figure above. This boat reached point A after 2 hours at a constant speed of 10 miles per hour, making a positive angle α with the direction [BC] from point B.

[AC] ⊥ [BC] and arcsin (3/5) = (π/2)-α then, how many miles is |BC|?

Figure 3. Sample question 2.



The positions of the two boats, Bambi and Can, which are making an island tour in Ayvalık, are modeled with the ABC triangle when they stop near Çiçek Island, as shown in the Figure above.

If |AB| = 60m, |AC| = 100m, and |BC| = 140m, how many degrees is (BAC)?

Figure 4. Sample question 3.

4.1 Methods

A case study provides us with in-depth and vivid descriptions in a real-life context (Duff, 2008; Eisenhardt, 1989; Yin & Davis, 2007). Thus, a case study has many advantages, such as recognising the complexity, and helping capture unique features that may otherwise be lost in larger-scale data that observe a broader reality (Cohen, Manion & Morrison, 2007). Given these advantages, the present study was planned as a case study. As an empirical method, this case study sets out to investigate the trajectories in depth and within their real world to develop mathematics literacy including CLIL for maths classes in upper-secondary education in Turkey. While planning this case study, drawing on Adelman, Kemmis and Jenkins (1980), focus was given to opportunities to collect, check and triangulate data (including peer examination of the findings, respondent validation and reflexivity).

A needs analysis was conducted to identify students' needs when implementing CLIL in mathematics education (Rach, 2023; Schukajlow, Rakoczy, Pekrun, 2023) in order to identify mathematical terminology in English. As discussed by Illés and Bayyurt (2023), we need practical perspectives to better prepare our students for the reality of how the English language is used today in maths.

In this study, the data were collected using structured observation given that observational data are beneficial as they allow the researcher to collect 'live' data from 'live' situations first-hand. Also, structured observation is systematic and enables the researcher to generate quantitative data from the observations. In the structured observation form, it was recorded how active the students participating in the study were in the lessons, their level of English, their mastery of mathematical terminology in English and their gestures and facial expressions during the lessons. A structured interview with students, who were the participants of the study, was used to accompany the observation. The interview questions were about CLIL, the course process, students' feelings of involvement in the course and differences from other courses. Observational data enabled the practitioner-researcher to enter and understand the situation that is described in this study. The interview data allowed the

practitioner-researcher to reveal the issues that might otherwise have been unconsciously missed (Cohen et al., 2007). The observation and interview data were analyzed using content analysis. In the coding process of the content analysis, a deductive coding approach was used. This is a top-down approach where the researcher starts with a set of predetermined codes and then finds excerpts that fit those codes. The codebook was developed with possible codes predicted by the researcher, and after checking data, some new codes were added into codebook.

4.2 Participants

In this study, there were 38 11th and 12th-grade students in a state secondary school in western Turkey. Twenty of the students were female and 18 were male. Their socio-economic status was similar and mostly low. The native language of all students was Turkish, and students were learning English as a foreign language. The students' English language proficiency level was mostly at A2 level, with a few students at B1 level, according to the Common European Framework of Reference for Languages (CEFR). Their mathematics proficiency level was good.

The researcher in this study is a mathematics teacher, and has a Master's in Science in Secondary School Science and Mathematics Education from Bogazici University, Istanbul, Turkey; the medium of instruction of Bogazici University is English. Thus, although the maths teacher's native language is Turkish, he is able to teach mathematics in English and is very familiar with the English terminology of maths. In this study, the mathematics teacher implemented CLIL classes for an hour a week for almost two months.

5. Implementation and Results

Ten mathematics questions about trigonometry were chosen from the mathematics textbook. As the medium of instruction in the upper-secondary school where this study was conducted was Turkish, the mathematics textbook was in Turkish. The Turkish mathematics questions in this study were translated into English by the practitioner-researcher before the mathematics classes. Then, students were asked to read mathematics questions in English. None of the students understood the

questions, because of the unknown words. The researcher asked students to note down the unknown words in order to prepare a vocabulary part for course notes and also explain them in the course. When the data for the unknown words were analyzed, there were target words in mathematics questions in English that were identified, such as *tangent*, *circular*, *exponential*, *pendulum*, *stationary* and *constant*, which students reported as unknown English words which they had to know in order to understand the questions in mathematics, as shown in Figures 5 and 6 below.

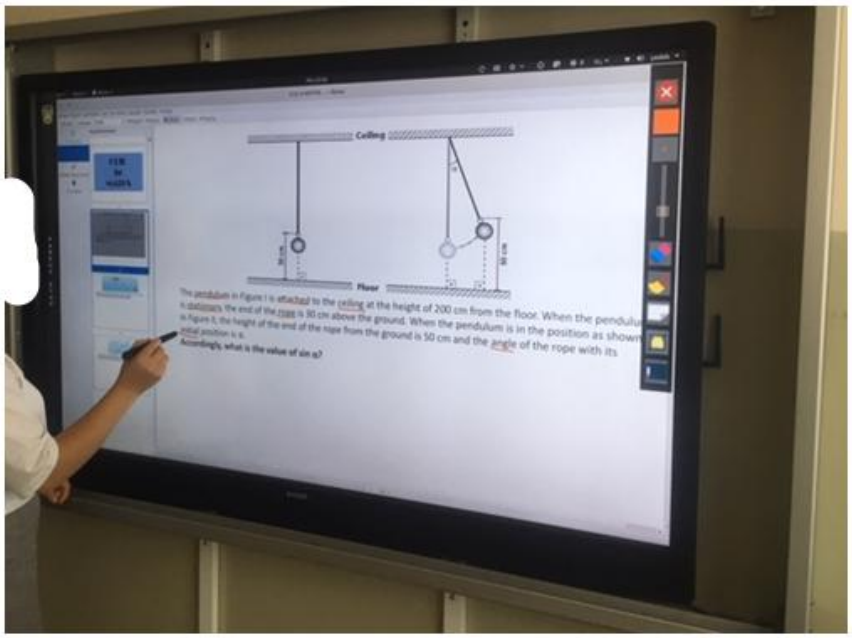


Figure 5. Student underlining and writing unknown English words and terms in a mathematics question

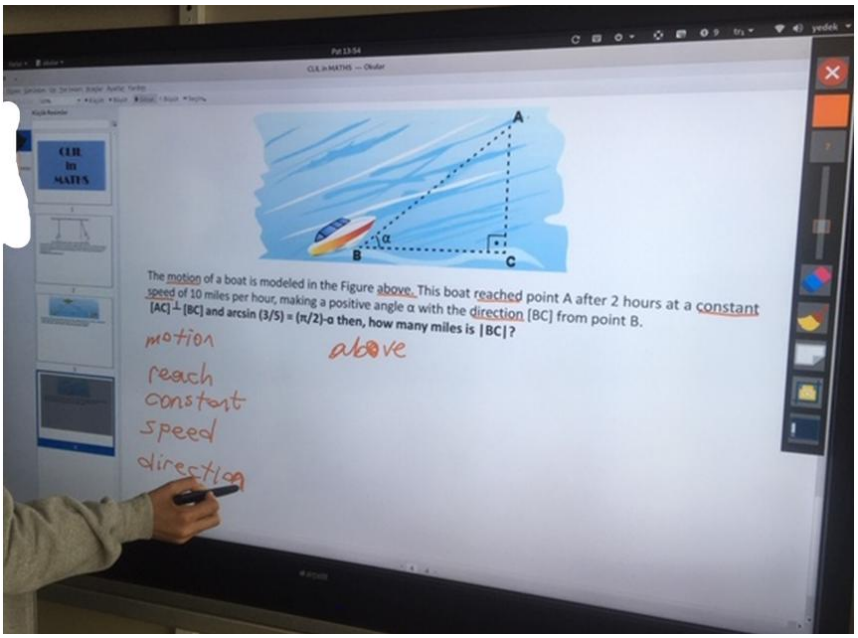


Figure 6. Student underlining unknown English words and terms in a mathematics question

As can be seen in Figures 5 and 6, each student chose different means to report the unknown words in English in mathematics. In Figure 5, the student underlined the words, while the student in Figure 6 both underlined and listed the words. The researcher then explained these words and terms to students in English, and students were able to answer the questions in mathematics in English (see Figures 7, 8).

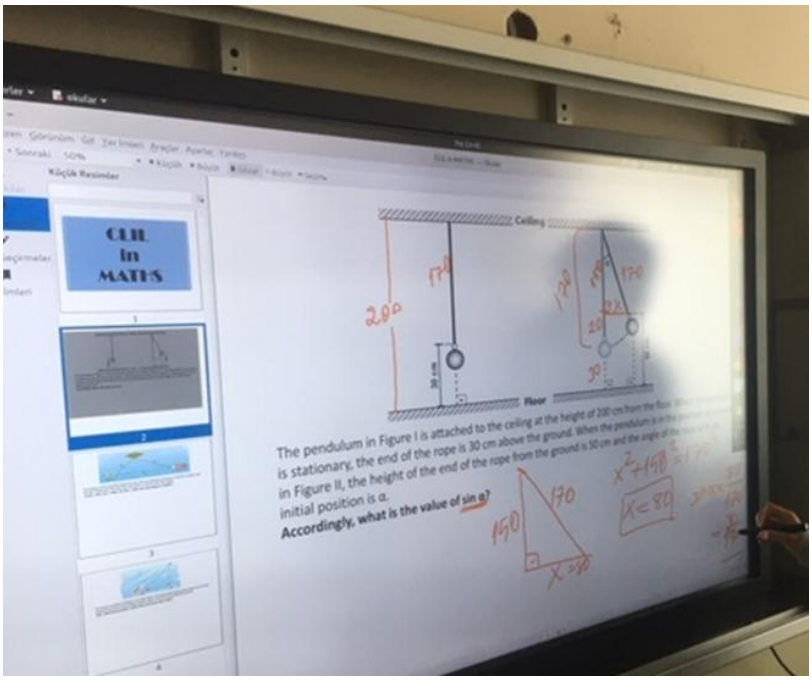


Figure 7. Student answering a mathematics question after mathematics teacher's explanations of unknown words and terms

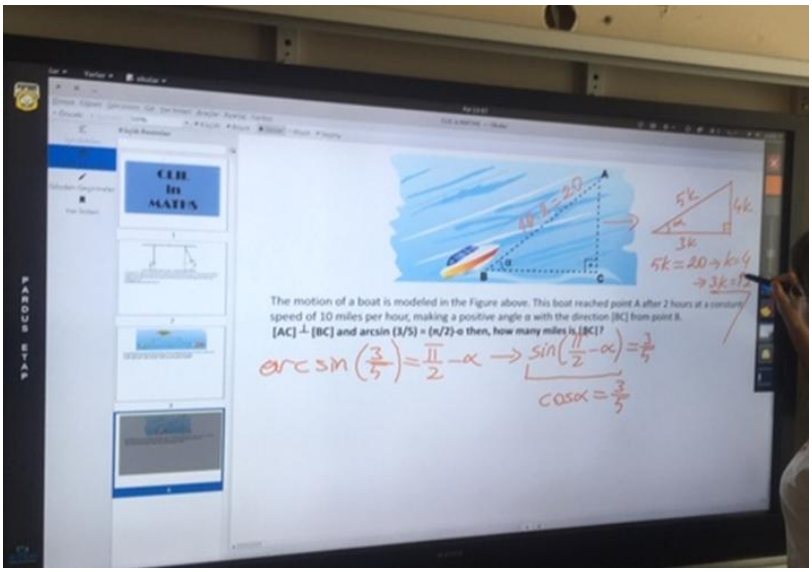


Figure 8. Student answering a mathematics question after mathematics teacher's explanations of unknown words and terms

After the CLIL lessons, face-to-face recorded interviews were conducted with the students. In these interviews, the students were asked pre-prepared questions about what they thought about the CLIL approach, how they felt about the CLIL lessons, how mathematics and language learning would change with this approach. An example of one of the interviews is presented below in Table 1.

Table 1. An example from interviews with students.

What are your thoughts on the CLIL approach?	From what I have witnessed, CLIL is a method that aims to teach mathematics and English together.
How did you feel during CLIL lessons?	Although my daily English is good, it was difficult to understand the lesson at first because I did not know the English of mathematical terms. But as I learned the terms, I began to understand what was taught more easily. I also became more confident in reading and speaking English. I think being able to understand and use foreign sources is another plus of this approach. I think it's more fun to learn English this way.
What do you think about having some of the classes in English?	I don't have any difficulty in courses such as mathematics and physics, other than learning the terminology, but I think I will have a hard time in more verbal courses such as history, biology, geography and literature.

Table 1 shows that at the end of this study, students had an idea about the CLIL approach. They shared how this practice made them feel and explained the good and bad aspects of the CLIL approach in their opinion. The majority of students showed a positive attitude towards CLIL implementation and stated that they found it beneficial for language learning and acquisition.

The data obtained from the interviews with the students are associated with the previously created codebook and shown in Table 2 with examples.

Table 2. Codes for data from the interviews with the students.

Coding category	Code	Examples
Students' feelings about the lessons	Enjoyable	The classes were very fun. I enjoyed the group work very much.
	Interesting	Listening and speaking English in math class was an interesting experience for me.
	Different	It was a different experience than I've had before and I would like all classes to be like this.
	Boring	I have trouble with mathematics and it was very boring to try to understand a lesson in a foreign language that I could not understand in my native language.
	Terrifying	I had a hard time in class and was very scared of the possibility of the teacher asking me questions.
Students' thoughts on the difficulty of the lessons	Easy	Once I learned the math terms in English, the lessons were very easy.
	Not different	It wasn't much different from our other math courses, except for the mathematical terminology.
	Difficult	Although I was good at math, the lessons were very difficult for me because my English was bad.
Students' thoughts on the CLIL approach and bilingual education	Useful	I think it is very useful to learn both math and English at the same time, so we can benefit from resources in foreign language.
	Efficient	In my opinion, it is a very effective method for learning a foreign language. If at least some of our classes were taught in English in primary and secondary school, my English level would have improved a lot.
	Unnecessary	I would like to learn English in English class and mathematics in mathematics class. I think it is a very unnecessary implementation.
	Useless	While the university entrance exam in our country is conducted in Turkish, learning

		mathematics and other courses in English is useless and unnecessary. It may even be detrimental to exam success.
Changes in students' attitudes towards mathematics	Better	I love both math and English lessons. Having both together made math more enjoyable for me.
	Not changed	I love mathematics. It doesn't matter to me what language it is in. Because mathematics is universal, and so is its language.
	Worse	I study hard for mathematics and I want to be successful. But I had a hard time in these lessons where the CLIL approach was used. I couldn't understand most of the things. Frankly, I've been alienated from mathematics.

As stated in the method section, the codebook was previously prepared by the practitioner-researcher. However, as can be seen from Table 2, the codes *different*, *terrifying* in coding category 'Students' feelings about the lessons', *not different* in coding category 'Students' thoughts on the difficulty of the lessons' and *useless* in coding category 'Students' thoughts on the CLIL approach and bilingual education' were added to the codebook based on the students' responses after data analysis. In the examples column, one example from the students' responses in the data was selected and placed in the table.

In addition, during CLIL lessons, the students' attitudes towards the lesson, their gestures and facial expressions, their dialogues among themselves and their reactions towards the teacher were observed by the researcher and these observations were noted. The findings obtained through both interviews and observation notes showed that the students' attitude in this study was very positive and students expressed that they could learn English and mathematics content with this implementation easily and in a more enjoyable way. This finding is consistent with the interview data and the previous studies in the literature (see Coyle, Meyer, & Staschen-Dielmann, 2023; Goris, 2023; Novotná & Hofmannová, 2000; Orozco& Pedrosa, 2022). In the interview data analysis, it was revealed that there was an increase in students' awareness of the

positive effects of CLIL implementation for their mathematical skills development, especially in solving verbal problems. Also, considerable positive effects on their view of learning English were observed. A surprising finding was that students were observed searching for mathematical terms in English that had not been addressed in the CLIL classes, such as *exponential*. This finding suggests that a CLIL class might foster learner autonomy. It was also observed that students' motivation to study increased, which is in line with the findings of studies conducted by Schukajlow et al. (2023), Arnandiz et al. (2022), Önder-Özdemir (2023) and Vlasenko et al. (2020). CLIL experts were contacted as external assessors for this study. One assessor, an EFL professor from Turkey who has studies on the CLIL approach, recommended at least two hours of CLIL classes in a week to increase the permanence and impact of lessons. The second assessor, a CLIL teacher from Italy, suggested project and task based learning to integrate CLIL classes.

6. Conclusion

The present study reported the steps followed to develop mathematics literacy for bilingual education in a state secondary school in Turkey. The steps in the present study suggest that while implementing CLIL, student-teacher interaction accompanied by a needs analysis can be the first step that can tailor the tasks and also facilitate both content and language learning to implement CLIL effectively. The steps in this study can be adapted to different levels of education where CLIL implementation aims to be utilized. When teachers design activities by tailoring them to students' needs, CLIL classes can be more successful. It is notable that in contrast with a traditional language learning approach, CLIL is student-centered. In this study, students determined the words and terms they did not know as a class, and after the teacher provided the necessary information, the students solved the questions. Students are at the center of the learning environment. The teacher took on the guiding role. This study has some limitations. Firstly, this is a preliminary study and is limited to one school. Secondly, the time frame was a limitation because students in this study were observed for eight consecutive weeks because the school administration granted eight weeks of leave for this study. Thirdly, this is the researcher's first study on CLIL and first implementation.

Further research should be conducted, especially over longer periods of time to teach more topics in maths and provide terminology knowledge in different contexts and with different age groups.

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