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# Language-responsive mathematics teaching and AEN learners in a CLIL context

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**Introduction:** This study explores the experiences of students with additional educational needs (AEN) in Irish-medium education (IME) mathematics classrooms within a Content and Language Integrated Learning (CLIL) context. The research investigates how language-responsive mathematics teaching and adapted summative assessments impact AEN students' learning outcomes, addressing a critical gap in understanding the interplay between language proficiency and mathematical competencies in bilingual settings.

**Methods:** A case study design was employed in a single IME primary school, focusing on five AEN students aged 9–10 years. Over a five-week intervention, participants engaged in small-group, language-responsive mathematics lessons tailored to their needs. Two summative assessments—one standard school-approved and one researcher-designed with language adaptations—were administered post-intervention. Data sources included teacher observations, reflective journals, and assessment results, analyzed through thematic coding and descriptive statistics.

**Results:** The findings revealed that while language adaptations in assessments had minimal impact on overall performance, language-responsive lessons supported student engagement and understanding. Participants demonstrated improved confidence and participation, though challenges persisted in transitioning from concrete to abstract concepts and in language-intensive topics such as probability. The summative assessments were limited in capturing students' full mathematical abilities due to cognitive and linguistic demands.

**Discussion:** The study highlights the potential of language-responsive teaching to enhance learning outcomes for AEN students in CLIL contexts. While adapted assessments showed limited efficacy, the pedagogical approach effectively addressed cognitive and linguistic challenges. Future research should explore scalable strategies for integrating language and content learning to support diverse learners in bilingual settings.

KEYWORDS

CLIL, Irish-medium education, AEN learners, Mathematics, language-responsive teaching

## 1 Introduction

Language, and proficiency in the language of instruction, is essential for the learning of mathematics (Barwell et al., 2016). Empirical evidence demonstrates that deep or conceptual learning of mathematical concepts is related to learners' proficiency in the language of instruction (Erath et al., 2021). Accordingly, language-responsive teaching and pedagogy has emerged as a pedagogical approach to support the teaching of mathematics to students with lower proficiency in the language of instruction and primarily implemented with multilingual learners of mathematics (Prediger and Neugebauer, 2021). Language-responsive teaching, closely linked transformative pedagogies such as translanguaging (García and Wei, 2014),

requires teachers to not only know and foster all their students full language repertoires but also, specifically in CLIL contexts, understand content and language demands so that they can be scaffolded appropriately according to the principals of language and content learning to ensure the successful acquisition of both (Karpava, 2024; Lucas and Villegas, 2013; Lucas et al., 2008). However, research examining language-responsive teaching with diverse groups of students remains scarce (Lenz et al., 2024). The primary aim of this research is to investigate a language-responsive mathematics teaching case-study with primary school pupils ($n = 5$) with additional educational needs (AEN) within a content and language integrated learning (CLIL) setting. CLIL is often defined as a 'dual-focused' approach (Coyle et al., 2010, *p*. 1) to the learning of disciplinary content communicated and mediated through an additional language and commonly applied to the learning of subjects through English. However, given the fact that CLIL provision has 'burgeoned through Europe' (Merino and Lasagabaster, 2018, *p*. 17), leading to an array of interpretations because of regional, national, and international differences in education settings (Coyle and Meyer, 2021, *p*. 5), the meaning of CLIL has diversified. In addition, the study sought to examine the impact of language-adapted summative assessments on the mathematics performance of this cohort of pupils.

The CLIL context underpinning this study relates to the provision of Irish medium education (IME), and specifically to primary schools known as Gaelscoileanna. Immersion education in Ireland, which promotes additive bilingualism in English and Irish in different subject areas, has existed since the 1950s (see Ó'Duibhir, 2018) and is likely to be one of the oldest forms of content and language integrated learning in Europe. In IME schools, all curriculum subjects are taught through the medium of Irish (except for English as a curriculum subject) in all 8 years of primary education (approx. Age 5–13). Therefore, the focus is on teaching content (e.g., fractions) through Irish, rather than on the teaching of the Irish language itself. Within the Irish educational system pupils with AEN are identified using the guidelines on a continuum of support published by the Department of Education and Science (2007). In this article, AEN will refer to a broad spectrum of diagnosed and undiagnosed needs including Dyslexia, Autism and Attention Deficit Hyperactivity Disorder (ADHD) as well as those who present in school as having difficulties with mathematics and language processing. Pupils with AEN in IME schools are a minority, which in turn contributes to limited resources being made available to support these pupils and limited research undertaken to date (Barnes, 2024). While developing literature acknowledges the need to cater for diverse students in CLIL contexts, the examination of specific pedagogical approaches remains under-researched (Madrid and Pérez Cañado, 2018). Accordingly, the contribution of this case study is twofold: it examines language-responsive mathematics teaching and assessment with AEN pupils and its potential as a pedagogical approach to cater for diverse learners in a CLIL context. The research questions underpinning this project are:

1. In what ways does a language responsive approach to teaching mathematics cater for AEN learners in a CLIL context, with a focus on languages other than English?
2. How do language-adapted summative assessments impact on the mathematics performance of pupils with AEN in primary IME?

## 2 Irish-medium CLIL and immersion education

Much of the research cited in this article draws on the fields of Content and Language Integrated Learning (CLIL), Immersion Education (IME) and Content Based Instruction (CBI). All three approaches share inherent characteristics and, as such, can provide useful theoretical and empirical evidence to develop an understanding of the teaching of mathematics through an L2. Of all the terms, CLIL and CBI are probably the most similar and can be interpreted as such given their similar educational goals in that learners acquire both an additional language and content simultaneously, each supporting the development of the other (Lyster, 2007) but not necessarily in equal measure: that is, some may be 'content-driven' and others 'language-driven' (Stoller, 2008, p. 59).

CLIL practice and research is often associated with the acquisition of English, particularly in Europe, whereas CBI, emerging from its origins in Canadian Immersion programs, has been associated with French as well as English (Brinton et al., 1989) and, as such, as they may have historically unique origins but are pedagogically unique (Cenoz et al., 2014). The forms and approaches to CBI and CLIL often differ according to the educational level and may have various positions within the school curriculum. Moreover, CLIL and CBI-based learning can take place in language learning environments or subject-based alternatives and can take place in discrete disciplinary areas, like history or mathematics, or can appear within subjects as part of a project, unit of learning or finite sequence of learning (Cenoz, 2015). The choice of additional language is often motivated by sociolinguistic reasons whereby learners may learn a majority language such as English or Spanish for neoliberalist reasons or a minorised language such as Irish or Galician as part of a wider language normalization policy. Majority languages can also exist as memorized languages in some contexts such as French in Canada and benefit from similar approaches for the same sociolinguistic outcomes. The sociolinguistic status of the L2 can also enhance or hinder the learning experience.

IME can either be seen as a subtype of CLIL or CBI or as a separate phenomenon. In terms of definition IME and its position in relation to CBI and CLIL, many see it as a variety of CLIL and CBI rather than a separate entity (Met, 1998; Dalton-Puffer et al., 2010; Massler et al., 2014) that can begin at an early, middle or late stage of a learners' education. For example, Massler et al. (2014) define it in terms of the percentage of the curriculum that is taught through an additional language from partial to total: in this case, 50%. However, key differences that demarcate IME from CLIL and CBI are that the overall educational goal is additive bilingualism rather than the acquisition of language and content.

The important conclusion from this short comparison is that all approaches discussed above present similar opportunities and challenges when it comes to the integration of content and language when teaching mathematics. The linguistic competence of learners in immersion contexts may advance quicker than those whose exposure to CLIL or CBI is piecemeal and may favor, therefore, the teaching of mathematics given the correlation that exists between language and mathematical proficiency.

## 3 AEN learners, mathematics and CLIL learning contexts

There is an assumption that CLIL settings such as IM schools contain a disproportionately large number of academically bright

students (Madrid and Pérez Cañado, 2018). While this may be historically a truism of CLIL provision in Europe (see Paran, 2013; Bruton, 2013, 2015; Pérez Cañado, 2016), current research related to AEN in IME shows that this is not the case. It is estimated that 9.4% of primary school pupils who attend an IME school have a diagnosed AEN (Nic Aindriú et al., 2020). Within the context of receiving additional support, which does not require a diagnosis, 16.6% of students in IME schools fall into this bracket. It is worth noting that this figure is not dissimilar to those of English-speaking schools (Nic Aindriú et al., 2020), a fact that is also supported by data related to similar allocations of additional teaching hours and Support Needs Assistant (SNA) hours across Gaelscoileanna and English-medium schools (Department of Education, 2022, p. 21). Consequently, IME education has the potential to offer a 'leveling effect' (Halbach and Iwaniec, 2020) whereby the traditionally elitest study of languages is opened to a wider, more diverse audience. It should be acknowledged here, however, that while this leveling effect may exist in the context of AEN, the same cannot be said for other diverse groups such as those who do not hold Irish citizenship, as only 1% of those enrolled in Gaelscoileanna do not have Irish or Dual-Irish nationalities whereas across the whole primary sector this figure is 10.4% (Department of Education, 2022, p. 22).

The emerging diversity in the IME sector in Ireland is not a new phenomenon in IME research. Indeed, the (in) famous study by MacNamara (1967) that warned against the negative effects that immersion education could have on L1 proficiency and that was later rebuffed by Cummins (1978) who argued that good quality immersion provision can provide learners with higher levels of proficiency in L1 and L2 is an argument that potentially still frames educators and parents' views of IME. It is for this reason that most research focusing on AEN in CLIL settings (Pérez Cañado, 2021; Pérez Cañado et al., 2023; Bauer-Marschallinger et al., 2023; Casas Pedrosa and Rascón Moreno, 2023) explores the perceptions of CLIL, its educators and learners from various stakeholders' perspectives. There has also been a concerted focus on more situated research in the form of case studies (Roiha, 2014; Roiha and Polso, 2018). Research focusing on IME is also seeing a shift toward catering for diversity, particularly from the parental perspective with regards to their children attending IME schools when they have AEN (Nic Aindriú et al., 2024; Spollen, 2021). What is clear from the current research agenda is that CLIL learner cohorts are increasingly diverse and, like any other mainstream classroom, have diverse needs.

This new focus on AEN in CLIL learning and teaching requires the discipline and educators to look beyond the traditional boundaries of Applied Linguistics or Education into other areas such as Communication and Applied Psychology that not only furnish us with interdisciplinary theoretical principles but also practical, research-informed pedagogical models that can assist in the process of designing successful content and language integrated learning sequences for learners that have AENs (Ruiz-Cecilia et al., 2023). The urgent need for research in this arena is supported by existing research (Andrews, 2020; Bialystok, 2001) that show that when learners do present with L1 competence challenges, such as Dyslexia or language processing disorders, AEN learners can struggle with the acquisition of integrated content (skills) and language, particularly in mathematics (MacKenzie et al., 2022; Erath et al., 2021), where the interplay between the two is inherently complex and inseparable (Schleppegrell, 2007).

## 4 Relationship between mathematics and language

In the context of learning mathematics, language serves many essential roles and exists in several different forms. Pimm and Keynes (1994) delineate five features of mathematical communication, presented here in no specific order. Firstly, the genre and register of mathematics are a constellation of choices (Schleppegrell, 2007, p. 431) from discourse to lexico-grammar to sound, each of which are chosen according to the expected social conventions of mathematics to build meaning for a socio-communicative goal (Martin and Rose, 2003, p. 7). In a mathematics IME classroom, this entails considering what use of language is not only appropriate for learners of this age but also within the discipline of mathematics. Secondly, the spoken language of the classroom, used by teacher and student, conceptualized as Basic Interpersonal Communication Skills (BICS) and Cognitive Academic Language Proficiency (CALPS). BICSs entails general conversation and function in everyday life. CALP on the other hand, is the specific terminology and knowledge necessary to participate in academic tasks (Cummins, 2000), both of which develop 'within the matrix of social interaction' (Cummins, 2000, p. 74). Moreover, in the mathematics classroom, BICs can also function as a pedagogical technique to elucidate the genre and register of mathematics, involving both cognition and communication. Halbach (2012) has even revised the original conceptualization of BICS as Basic Interpersonal Cognitive Skills to acknowledge the thinking role when using this form of language and communication. The third type of language is the inner monolog or language of mathematical mediation produced by students when processing internally (Prediger and Neugebauer, 2021), which may occur in an L1, L2 or plurilingually. Fourth is the written language of texts in classrooms that adhere to academic and genre conventions but are adjusted for learners' age and stage in acquiring mathematical literacy. Finally, the language of written symbolic forms and graphical constructs and how they represent meaning, communicated through both BICS and CALPS, require another level of literacy of their own (Schleppegrell, 2007). For example, the graph of a quadratic function could be communicated as: (i) The parabola intersects the axes at the root of the function or (ii) The curve crosses the line at 1. The use of language, graphical representations and symbols also reinforce the multimodality of mathematical communication.

The complexity of mathematics-based communication for learning is further complexified when considered in IME contexts. When this undertaking is then required in an L2 where the mathematical discourse is communicated in conjunction with content, the need to be linguistically responsive is heightened. A teacher needs to have higher levels of general and disciplinary specific metalinguistic awareness, what might be termed Language Knowledge for Content Teaching (Morton, 2018), which includes both Common Language Knowledge and Specialized Language Knowledge. This is required both for receptive and productive communication in the classroom. Simultaneously, teachers are required to not only be proficient in CLK and SLK (see Poo, 2021; Feryok, 2008) but also understand how to mediate such language so that it is appropriate for their emerging content and language needs as well as their levels of cognitive maturity (Han et al., 2021), particularly when dealing with mathematical word problems (Abedi and Lord, 2001).

The current research landscape in relation to language-responsive teaching in mathematics is limited in that it focuses principally on multilingual contexts where learners' L1s are different to the language of schooling, usually English (Kaukko et al., 2022; Porter, 2021; Song and Coppersmith, 2020; Hernandez and Shroyer, 2017; Bottoms et al., 2017). Some emerging research is examining the impact of language-responsive learning materials in heterogeneous mathematics classrooms but the need for examination with diverse groups of learners is evident (Lenz et al., 2024). It is understandable that there is limited research language-responsive teaching in CLIL or IME contexts given the inherent focus on language in this arena. One analogous research area is that related to linguistically responsive practices and how they reinforce the correlation that exists in mathematics classroom between learners' mathematical and linguistic proficiency and fluency, particularly when learning through an L2 (Joutsenlahti, 2010; MacKenzie et al., 2022; Ouazizi, 2016). This has been suggested is probably because of their heightened levels of linguistic awareness that are enhanced when learning content and language together (Surmont et al., 2014) and, as a result, language proficiency is a strong predictor of mathematical academic achievement.

It is, therefore, sensible to suggest that when the challenge of AEN is also included in this interplay, particularly when the need is language based, the challenge of integrating content and language is heightened. Current research is sparse in relation to AEN, Maths and CLIL, however, what does exist generally centers on language responsive practices such as code-switching (Papaja and Wysocka-Narewska, 2020) and translanguaging (Tai, 2022; Wei, 2018) through L1, L2 and L3, including allowing learners to choose what language they respond with in assessments (Tihonen, 2020). Translation, however, is not recommended as this can actually have adverse effects on weaker students and diminish the role of the L2, especially if it is a minorised language (Tan and Lan, 2010). Other strategies include, language awareness strategies (Tavares, 2015), adopting Task Based Language Learning approaches (Moore and Lorenzo, 2015), the use of playful talk (Wei, 2018), devoting more instructional time to reading and writing in the L2 in mathematics lessons (Mahan et al., 2021) and simplifying language (Tihonen, 2020). Caution should be observed, however, when simplifying. Dalton-Puffer warns us that if educators believe in making a difference and providing equal opportunity then educators 'must strive to give learners access to the *genres of power*, which pertain to the domain of written texts' (Dalton-Puffer, 2013, p.225). While mathematics may not be akin to traditional written texts, the power of numeracy for social mobility is undeniable and the need to support learners to reach age and stage appropriate levels of mathematical fluency and proficiency whether that is in an L1 or L2 is essential.

One potential pedagogical model that might prove useful in mathematics is the area of Cognitive Discourse Functions (CDFs) (Dalton-Puffer, 2013), which combines the linguistic, content, and cognitive strands of mathematical content-discourse together and could play a key role in helping IME educators to support AEN learners. CDFs are communicative practices that students use to engage in disciplinary thinking and learning, enabling learners to process and articulate simultaneously their understanding, reasoning and knowledge construction through high order thinking functions. CDF categories include *classify, define, describe, evaluate, explain, explore* and *report,* all of which have subcategories, e.g., the category *classify* is accompanied by *compare, contrast, match structure*, etc. Each of these categories and subcategories have inherent communicative intentions. Therefore, when you classify something, an educator might expect a learner to 'tell you how we can cut up the world according to certain ideas' (Dalton-Puffer, 2013, p. 235). They are both classifying cognitively and communicatively simultaneously and thus integrating content and learning. In relation to summative assessments in which learners are required to know, understand and show their ability to do mathematics and language simultaneously, CDFs help educators to conceptualize and plan not only the learning that they wish learners to demonstrate but also the language through which they will demonstrate it, a key reported difficulty in the IME context (Nic Aindriú et al., 2020). Moreover, when it comes to learners who have additional needs, CDFs and its subcategories help educators to scaffold and plan the integrated language and learning expectations of and cognitive load (Leung et al., 1997) placed on their learners until they reach the expectations of the genre and register of mathematics for their age and stage.

## 5 Research design and implementation

A case study approach is a research strategy used to gain an in-depth understanding of a specific subject, phenomenon, or entity within its real-life context, as advocated in CLIL-based research by Coyle et al. (2023). This research centers around a single school case, with five AEN pupil participants. The case is selected because it is particularly useful in answering the research questions established above (Yin, 2018). Moreover, key voices in the CLIL research landscape have argued that associated research should always be considered through a 'context-sensitive' lens (Hüttner and Smit, 2014, p. 164). A case study approach lends itself to this endeavor.

The designed intervention sought to respond to the challenges that emerge for AEN pupils required to complete summative mathematics assessments, one function of which is to identify potential AEN learners. A five-week language-responsive unit consisting of four lessons per week was designed and implemented with the participants. Participants completed two summative assessments at the end of the period – one the required assessment by the school known as 'Gafa le Mata' (GLM) and a language-adapted version of this assessment developed by the teacher-researcher (RDA).

### 5.1 Design principles informing the implementation of the study

To answer the primary research questions of this project, it was necessary to consider the design principles required to create language-responsive lessons and a language-adapted summative assessment. The mathematics register consists of specialized vocabulary, words, phrases, and methods of arguing within a given situation, conveyed using natural language (Pimm, 1987). Each language will have its own distinct mathematics register and ways in which mathematical meaning is expressed in that language. For example, the mathematics register in English is different to the mathematics register in Irish (Ní Ríordáin, 2018). This reinforces the view that the content of mathematics is not taught without language, and the process of learning mathematics involves the mastery of the

TABLE 1 Table of weekly lessons.

| Week | Topic | Objectives |
|---|---|---|
| 1 | Measures-Money | • Rename amounts from euro to cent and from cent to euro.<br>• Order amounts of money in terms of value<br>• Solve and complete one-step problems and tasks involving the addition and subtraction of money |
| 2 | Number - Multiplication | • Recall multiplication facts x3, x6, x9<br>• Solve and complete practical tasks and problems involving multiplication of whole numbers |
| 3 | Number – Division Algebra – Number Sentences | • Can identify the division (÷) sign and understand division as repeated subtraction (÷ 3).<br>• Can solve and complete practical tasks and problems involving division by 3, 6 and 9.<br>• Can recall simple division facts – division by 9. Can solve word problems involving division by 6. |
| 4 | Algebra – Number Sentences Data - Chance | • Explore, recognize and record patterns in number<br>• Solve one-step number sentences<br>• Use vocabulary of uncertainty and chance: possible, impossible, might, certain, not sure<br>• Order events in terms of likelihood of occurrence |
| 5 | Measures - Time | • Record time in analog and digital forms<br>• Rename minutes as hours and hours as minutes |

mathematics genre and register. This aspect of mathematical classroom discourse was chosen as the focus of this study.

However, many difficulties in teaching mathematics arise from language related issues such as borrowed words, ambiguous terms, and specialist terms. As students with AEN operating in their second language in a CLIL context it was necessary to consider how best to structure the lessons to best meet their needs. Lenz et al. (2024) advocate for language-responsive instruction which involves adapting the materials and content to the students' language needs to overcome their lower levels of language proficiency. This project drew on some key researchers in the space of language-responsive mathematics teaching to develop guiding principles for the design of the series of lessons and the final language adapted summative assessment utilized in conjunction with the required summative assessment of the school. In particular, the work of Erath et al. (2021) provided key design features for enacting instruction that enhances language for mathematics learning. These include (Erath et al., 2021, p. 247):

- Engaging students in rich discourse practices, providing opportunities for them to explain meanings, construct arguments, and justify procedures.
- Establishing various mathematics language routines to support language learning and enable self, peer-, and teacher assessment.
- Connecting different language varieties and multimodal representations to help students understand the relationships between linguistic descriptions and representations.
- Including students' multilingual resources, such as code-switching and explanations in their home language, to support meaning-making in mathematics.
- Using macro-scaffolding to sequence and combine language and mathematics learning opportunities, starting from everyday experiences and gradually developing academic and technical language.

Table 1 provides an overview of the lessons presented in the format that is standard practice for this school context. It does not conform to the principals for CLIL planning as recommended by Coyle et al. (2010), especially in planning the language of the classroom as per the Language Triptych. The cognitive demands of encountering challenging language as well as mathematical concepts is high and can impede progress (Lenz et al., 2024). In addition, the following was considered (Schleppegrell, 2007).

- Multiple Semiotic Systems: Mathematics draws on multiple semiotic systems, such as symbols, oral language, written language, and visual representations like graphs and diagrams, to construct knowledge. These different systems have their own unique ways of expressing meaning, and students need to be able to understand and use these different systems effectively.
- Technical Vocabulary: Mathematics has its own technical vocabulary, which includes specific mathematical words like sum, fraction, place, borrow, and product. Students need to learn the meanings of these words and the specific language patterns and structures associated with them in mathematics.

Some research has found word problems/problems set in context to be the most challenging language aspect of learning mathematics (Ní Ríordáin, 2018). This was considered at both the planning, teaching and assessment stages. Some key principles included: planning the use of language in terms of the thinking required (CDFs); using gestures and objects to clarify meanings (Moschkovich, 1999); highlighting the specific meanings of words within the mathematical context, e.g., more than or less than, changing unfamiliar or infrequent words to more recognized alternatives, using active verbs rather than passive verbs, complex question phrases were changed to simple question words (Erath et al., 2021); abstract or impersonal presentations were made more concrete (Schleppegrell, 2007); and placing a joint focus on the language and the mathematics (Ní Ríordáin, 2018). Table 2 provides an overview of the language differences enacted between the two summative assessments administered.

## 5.2 Participants

This research was carried out in collaboration with third-class pupils (approx. Age 9–10 years old). This group consisted of five

students, identifying as girls and boys (see Table 3). This sample group was chosen as they had already been identified as pupils requiring additional support in mathematics. The school determined this based on their standardized test scores from the previous school year. As such, they met the criteria, as defined by Yin (2018), as being a group that can be easily distinguished from the wider context. Author three was the special education teacher assigned to this class, she had previously worked with this group and had identified their mathematical needs. She is referred to as the teacher-researcher in this study. The participants' parents had agreed to additional support from the special education teacher at the beginning of the year and were involved in their school support plans. As this group were already familiar with the teacher-researcher and that the interventions would form part of their everyday learning, the likelihood of their participation was more assured. The project was constructed to provide familiarity to the students and to be based on their current levels of support within the school. Some of the participants had received a formal diagnosis for specific learning difficulties. It is worth noting that these assessments were carried out in English and would not have accounted for their Irish language education (Nic Aindriú et al., 2024). The class teacher, Joan, also participated in the research. The structure of the lessons as well as the mathematical themes were chosen and planned in conjunction with her. Informal meetings were also held at the beginning, at the halfway point and at the end of the five-week period to gain her insights. This included how the participants were progressing during class time and to discuss the results of the assessments.

## 5.3 Data collection

A case study often involves collecting data from multiple sources such as interviews, observations, documents, archival records, and artifacts. This triangulation of data sources enhances the reliability and validity of the findings (Yin, 2018). While case studies are qualitative, they can also include quantitative data to provide a more complete picture of the case. The choice of methods for this study were driven by the research questions and the nature of the case (Yin, 2018). Table 4

TABLE 2 Table of differences between Gafa Le Mata assessment and researcher-designed assessment.

| Topic covered | Gafa Le Mata structure | Researcher structure | Reasoning |
|---|---|---|---|
| Number - multiplication | Multiplication grid used | Number sentence structure used | The multiplication grid is not commonly used and is difficult to interpret. |
| Money | Bhí €4.20 agam. Fuair mé 10c agus 50c. Anois tá €___ agam. | Cad é €4.20 **agus** 50c agus 10c? | Agus in bold to aid understanding. Shorter sentences to reduce reading. |
| Money | Cheannaigh Ciara stocaí. Cé mhéad a fuair sí mar shoinseáil as €5? | Cheannaigh Julie stocaí. Cén **soinseáil** a fuair sí as €5? | Julie used it as a familiar name to them. Soinseáil in bold to highlight what is required. Visual of the €5 Note also included to aid understanding. |
| Number — multiplication | Tá 6 chos faoi bhóin Dé. Cé mhéad cos a bheadh faoi 9 mbóin Dé? | Tá 6 pinn luaidhe i mbosca. Cé mhéad atá i 9 mbosca? | Ladybird swapped pencils as spots could cause confusion. 9 mbosca in bold. |
| Number — division | Na piorraí atá sa bhosca seo cuirfidh mé 6 cinn díobh i ngach mála. Cé mhéad mála a líonfaidh mé? | Cé mhéad úll an féidir a chur i ngach mála? | Six bags shown in question as visual aid. Question shortened and more direct. |
| Data — chance | Cuir in ord ón gceann is dóchúla. Rachaidh mé chuig an gcluiche sa Spainn ar: (visuals of boat, bicycle, aeroplane) 1 = is dóchúla 3 = is neamhdhóchúla | Cuir in ord ón gceann **is dóchúla**. Rachaidh mé go Spainn ar: (visuals of boat, bicycle, aeroplane) 1 = is dóchúla 3 = is neamhdhóchúla | Sentence shortened. Key phrase (is dóchúla) in bold. Irrelevant information removed. |
| Data — chance | Cén focal is fearr a chuireann síos ar an seans atá agam pionna éadaigh a roghnú sa mhála seo má tá dallóg orm? Scríobh an focal ___ | Cén **seans** go bpiocfaidh sí an **pionna**? | The structure changed from me to her, a visual of blindfolded girl inserted to clarify. |
| Measures — Time | Thosaigh clár spóirt ar 6:35. Chríochnaigh sé ar 7:20. Cén fhad a mhair an clár i nóiméad? | Thosaigh clár spóirt ar 6:35. Chríochnaigh sé ar 7:20. Cén fhad a mhair sé? | Visual of family watching tv included. A green symbol beside start time and red beside finish time also inserted for visual clarification. Question shortened to assist reading. |
| Number — multiplication | Ordóga san áireamh, cé mhéad méar atá ar 9 lámh? (Hand visual also) | Cé mhéad **méar** atá ar **9** lámh? | Méar and 9 in bold. Sentence about thumbs excluded to simplify. |
| Measures — Money | Cé mhéad oráiste is féidir leat a cheannach le 90c? | **Cé mhéad** oráiste is féidir leat a cheannach le **90c**? | Cé mhéad and 90c in bold. Visual of 90c in 50c, 20c and 20c coins included to clairfy what is required. |

TABLE 3 A table outlining the participants, their standardized test results from the previous school year and their diagnostic status.

| Participant | STEN score and percentile 2022/23 | Description |
|---|---|---|
| 1. Aisling | STEN 3 – 10th percentile | • Aisling has not been diagnosed with a formal learning need but has received support for mathematics based on STEN scores as per the DES Circular 0013/2017.<br>• When comparing Aisling's non-reading test results to her Irish test results, she performs within her ability. Her language skills would fall into the low average range. |
| 2. Caoimhe | STEN 3 – 13th percentile | • Caoimhe was diagnosed with Dyslexia in 2023. Her parents and teachers report mathematics as a particular area of concern for her.<br>• When comparing Caoimhe's non-reading test results to her Irish test results, she performs below her ability. Her language skills would fall into the low average range in Irish. Her Dyslexia diagnosis explains this discrepancy in performances. |
| 3. Jenny | STEN 3 – 9th percentile | • Jenny has not been diagnosed with a formal learning need but has received support for mathematics based on STEN scores as per the DES Circular 0013/2017. Jenny's performance in mathematics assessments is significantly lower than her scores in English and Irish.<br>• Jenny's language skills are in the average range. Her difficulties are maths based and do not appear to be linked with language. |
| 4. Mikey | STEN 2 – 3rd percentile | • Mikey has been diagnosed with ADHD, Autism and Dyslexia. Due to his complex needs he finds participation in mainstream schools challenging at times. Mikey works best when in a 1–1 setting.<br>• When comparing Mikey's non-reading test results to his Irish test results, he performs below his ability. He finds reading and speaking in Irish extremely challenging. |
| 5. Saoirse | STEN 3 – 6th percentile | • Saoirse is awaiting an assessment for a possible specific learning difficulty. She scored a STEN of 2 in her English and Irish standardized assessments. These results are in line with her non-reading test results. |

provides an overview of the various data sources utilized in this research project and collected by the teacher-researcher (February to March 2024). The data was collected sequentially, with the qualitative data gathered prior to the quantitative. Firstly, the series of lessons provided the opportunity to gather qualitative data in the form of observations by the teacher-researcher, and monitoring of progress to gain an understanding of the group's competencies. Observations were discussed with the class teacher at key points in the implementation phase, as well garnering this perspective on the participant's progress over the five-week period. These meetings were not audio recorded but rather part of the day-to-day work of teaching and planning for teaching. Notes were taken by the teacher-researcher during these meetings. The second phase involved the collection of quantitative data in the form of both the GLM termly assessment and the RDA. The qualitative and quantitative data were viewed as being equally weighted. This project was mutually dependent on both in answering the research questions. Despite the data being collected sequentially, a triangulation strategy was best suited. The data sources were collected to be compared 'to determine if there is convergence, differences, or some combination' (Creswell, 2009, p. 213) in the students' competencies during lessons and during assessments.

## 5.4 Data analysis

Thematic analysis was utilized for analyzing the qualitative data, as it is particularly effective in case studies where the aim is to identify patterns and themes within the data. It involved systematically coding the data and then organizing these codes into themes that capture significant patterns or meanings related to the research questions (Braun and Clarke, 2006). This method allowed the researchers to focus on identifying and interpreting the underlying ideas and concepts (Nowell et al., 2017). We then synthesized these themes to provide a nuanced understanding of the case and draw insights that may inform practice and policy (Vaismoradi et al., 2013). Descriptive statistics were undertaken on the summative assessment results to summarize and organize data to highlight key features, such as central tendency and spread (Creswell, 2009). This initial step was essential for understanding the basic structure of the data and identifying patterns. When comparing test results, descriptive statistics provide a foundation for further analysis by offering a clear overview of the data distribution and allowing for straightforward comparisons between performance on both assessments. The participants' results on both assessments were compared to determine if there was any difference overall and within questions, when the language was adapted. These results were also compared to their competencies observed by the teacher-researcher and the class teacher to determine the accuracy of representation of mathematics ability. The use of both qualitative and quantitative approaches enabled the integration of rich, detailed data to construct a comprehensive picture of the studied phenomenon.

# 6 Key findings and discussion

## 6.1 Participation and learning in lessons

Throughout the five-week period of the study the participants willingly joined the researcher outside of the classroom for thirty-minute lessons 4 days a week before returning to join their mainstream class for whole class mathematics lessons. The language-responsive lessons began by introducing and highlighting the key terminology

TABLE 4 Data collection approaches.

| Data collection approaches | Collection points | Reasoning |
|---|---|---|
| **Qualitative** | | |
| Reflective journal | Throughout five weeks of lessons | The qualitative data collection was done to build a profile of the participants. The effectiveness of the assessments in measuring their competencies could only be determined when compared to their progress on a day-to-day basis. Observing the participants allowed insights into the impact of language proficiency on their learning (MacKenzie et al., 2022) as well as their abilities to communicate (Cummins, 2000) and demonstrate understanding of mathematical concepts (Prediger and Neugebauer, 2021). Their attitudes and potential anxieties could be detected at this stage (Lenz et al., 2024). Consultation with the class teacher provided context to the progress and observations. She clarified if a small group language-responsive approach (Lenz et al., 2024) was having an impact on participants compared to their past experiences of mathematics lessons in a whole class CLIL context. |
| Samples of work | Throughout five weeks of lessons | |
| Meetings with class teacher | Three meetings - beginning, middle and end of five-week period | |
| **Quantitative** | | |
| Summative Assessments | End of five weeks | |
| GLM Assessment | First for two participants followed by RDA | In-depth study was achieved by analysing the results of both assessments (Denscombe, 2010). Answers to individual questions were compared to ascertain if the language adaptations are effective in improving participant understanding of what is required of them. The order of completion differed to determine if working memory played a role in assessment results (NSW Department of Education, 2017). |
| RDA Assessment | First for three participants followed by GLM | |

and phrases that would feature during each topic. Concrete manipulatives and visual supports were used at the beginning of topics, as multimodal resources helped to balance both language and content learning as advocated by Erath et al. (2021). However, as they were gradually withdrawn, the movement from the concrete to the abstract was an area of challenge for some of the participants. They found the tasks to be increasingly challenging without the aid of concrete supports such as a 100 square in the case of multiplication and the coins during money. It was noted in the teacher-researcher reflective journal that 'Aisling demonstrated she could locate correct answers to questions using the 100 squares but wrote 6×4 = 22 on her whiteboard when the visual cue was unavailable' (Reflective Journal, 27/3/24). Some of the participants, in particular Mikey and Saoirse, found the concepts challenging even while using the support materials. It was noted that 'Mikey needed teacher assistance to count forward in 4 s on the 100 squares, without a finger marking his previous position he frequently lost count' (Reflective Journal, 29/2/24). Saoirse was observed struggling to show €3.70 using the cent coins. She asked, 'how can I do this without any euro coins?' (Reflective Journal, 22/2/24). This was unsurprising as it had been highlighted in Moschkovich (1999) that manipulatives alone are insufficient in supporting students' mathematics education while operating in an additional language. She recommends that language be used in context and 'to clarify the meaning of the objects they are manipulating, looking at or pointing to' (Moschkovich, 1999, p. 12). It was challenging for the participants to communicate in Irish during these sessions and they often spoke English. The researcher often re-voiced their questions or comments into Irish. This has significant implications for the group's ability to further develop their mathematical knowledge. An ability to engage in rich discourse is a necessary skill for mathematics (Erath et al., 2021) Higher order skills such as problem solving require a grasp of both the language and the mathematics. If the group cannot use the language orally, even if it lacks accuracy resulting in imperfect mathematical discourse (Moschkovich, 2012), it is increasingly difficult for them to engage in written tasks and the development of their mathematical reasoning.

The lesson topics changed each week, in line with the monthly plans of the class teacher. Most of the participants appeared jovial throughout and did not express concerns in relation to the pacing. Mikey would occasionally express frustration during the lessons when he encountered an aspect, he found challenging. He would withdraw from the activity and refuse to make additional attempts. 'I cannot do this, it's too hard' was uttered repeatedly by him throughout the intervention. This was overcome by sitting beside him and providing more 1–1 support. The availability of this individual support was a necessity for him to access the curriculum. A meeting between the teacher-researcher and the class teacher took place during the final week of the intervention. Both agreed that the pacing was too fast and greater time spent on the topics would have been beneficial. 'I would have loved to have spent one more week on those six times tables' the class teacher remarked 'I really think it could have clicked then' (Meeting 3, 23/3/24). However, this was unavoidable as the topics were required to be covered prior to the GLM assessment as is school protocol. Existing research on working memory and cognitive load

theory suggests that more time is necessary to convert information from working memory to long term memory (NSW Department of Education, 2017). Moreover, Roussel et al. (2017) also argue that cognitive load is heightened when complex mathematical tasks must be navigated in a second language. While little research exists on students with AEN in CLIL contexts it seems plausible to suggest that the cognitive demand required to participate in mathematics in a second language may be restricting their ability to process the mathematical content as well as the language. We suggest that providing opportunities to experience deeper learning episodes would be beneficial for AEN learners in a CLIL context. Further research into this area is required.

The most challenging topic as reported by the participants, teacher-researcher and class teacher to teach was chance. This was the most language heavy topic and differed from the others in its lack of numbers present in the questions. While in most of the other strands the participants could always read the numerical figures, which do not change between languages, the chance topic required them to understand the language and the mathematical theory in question at the same time without the familiarity that numbers bring (Lenz et al., 2024). The participants had to grapple with several unfamiliar terms that are quite similar to each other. The key terms from this topic were 'seans ar bith' (impossible), 'drochseans' (unlikely), seans (likely), 'cinnte' (certain). These terms are remarkably similar and caused confusion for participants. There is little comparison to be made to their English translations and consequently the group could not rely on prior knowledge to assist them. It was observed that the participants could distinguish between scenarios that were possible or impossible but struggled to understand the difference between likely and unlikely. A question in their textbook asked them to choose how likely it was that the colored cubes would be chosen (see Figure 1). When asked how likely it was that the green cube would be pulled out from the scenario in 2a Saoirse responded 'seans ar bith' (impossible). It was noted in my reflective journal that she did not understand what each of the terms meant when used in Irish. The class teacher reported that even when she translated to English, confusion remained 'I asked her (Saoirse) how likely it was that the snowman on page 88 would still be in the garden tomorrow and she said likely' (Meeting 2, 10/3/24). The impact of her AEN is clear in this example, her lack of proficiency across both languages is impeding her progress in mathematics (MacKenzie et al., 2022).

## 6.2 Progression of learning

During the series of lessons, observations were made by both the researcher and class teacher as to the progress of the group within each topic. The group were also encouraged to self-assess and notes were kept of their commentary during lessons. Overall, each week, the reporting was positive among all participants with both teachers and students voicing their positive experiences. 'That was easier than I thought it would be' (22/2/24) said Caoimhe at the end of week two. 'Mikey's attitude was way more positive than usual coming back into the class' Joan reported (Meeting 1, 23/2/24). She also found that most of the group could participate in whole class maths activities and demonstrated an understanding of the content being covered during the intervention. 'Saoirse normally never raises her hand to answer a question but this week she did' said the teacher during week one. When asked to self-assess their work using a traffic light system (red = I found this difficult; orange = this was ok for me; green = this was easy) while with the researcher in week two, four of the five chose green while one chose orange. Saoirse rated herself as a green, however the notes taken during the lesson recalled that she found the task difficult and had relied on counting throughout. This points to their attitudes during the lesson rather than their abilities in mathematical concepts. Saoirse may have chosen green because she felt the lesson was a positive experience. Lenz et al. (2024) reminds us that learners' attitudes can have a significant impact on mathematical development, and it is worth considering that this may be at play with this group. Their research is among the first to acknowledge the link between language demands and mathematics anxiety and their effect on learning outcomes.

Multiplication was a prominent feature in week two of the intervention. It appeared again in the mainstream class setting in week five and informally throughout the period. The class teacher noted that the participants had failed to retain some of the key information during the intermittent weeks between covering the topic in the small group setting and a reintroduction in the classroom. This is evidenced in their workbooks; Saoirse's illustrates that she could complete the tasks successfully at the beginning of the intervention but was unclear of the concept once again in week five (see Figure 2). It is plausible that the CALPS (Cummins, 2000) required to understand the explanations received in class time is too cognitively demanding for students with AEN such as Saoirse and therefore more time is needed as well as more explicit instruction to convert the information to long term memory (Lenz et al., 2024; NSW Department of Education, 2017). There is a lack of definitive research in this area to provide more conclusive information.

## 6.3 Performance in summative assessments

The group completed their summative assessments in differing orders. Jenny, Mikey and Saoirse completed the researcher-designed assessment (RDA) prior to the GLM assessment. The RDA was completed on a Tuesday morning and the GLM assessment took place the next day, Wednesday. Aisling and Caoimhe completed GLM first on that same Wednesday, then the RDA was completed by Aisling the following day. Caoimhe was absent from school that Thursday and as a result completed her RDA upon return from the Easter break. This was initially set out to investigate if the order of completion would impact the results of the participants. Their results are presented in Table 5.

The differences in performances across the assessments are minimal. Caoimhe is the most significant, having scored 18% higher in the traditional assessment (GLM) than in the language adapted assessment (RDA). Mikey and Saoirse also performed better on their first assessment. Overall, the median score of the participants' first assessments was 55 while the median score of the second assessments was 52. Regardless of which assessment came first the scores are better on the first attempt. The median score for the GLM assessment was 59 and the median score for the RDA was 52. However, greater spread was observed in the GLM assessment (IQR = 25), than in the RDA (IQR = 14). This suggests that the results varied more in the GLM assessment, with the RDA providing a more stable assessment of participant learning. While it is difficult to determine what might have impacted on this, it is in line with the observations of the teachers during the lessons wherein the group grasped topics in the short term

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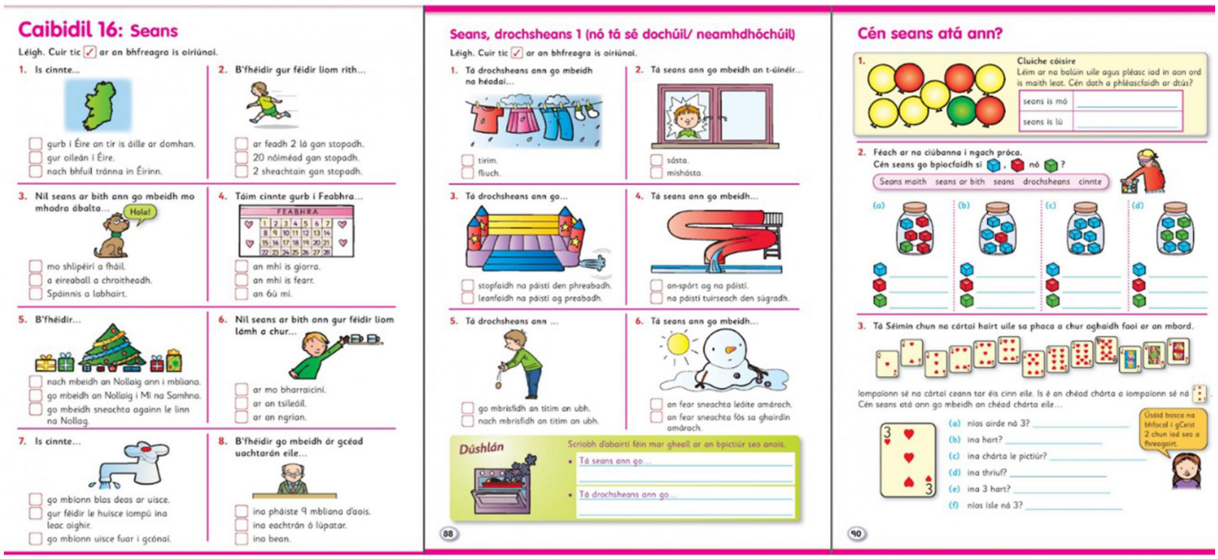


FIGURE 1
Chance questions in the textbook.

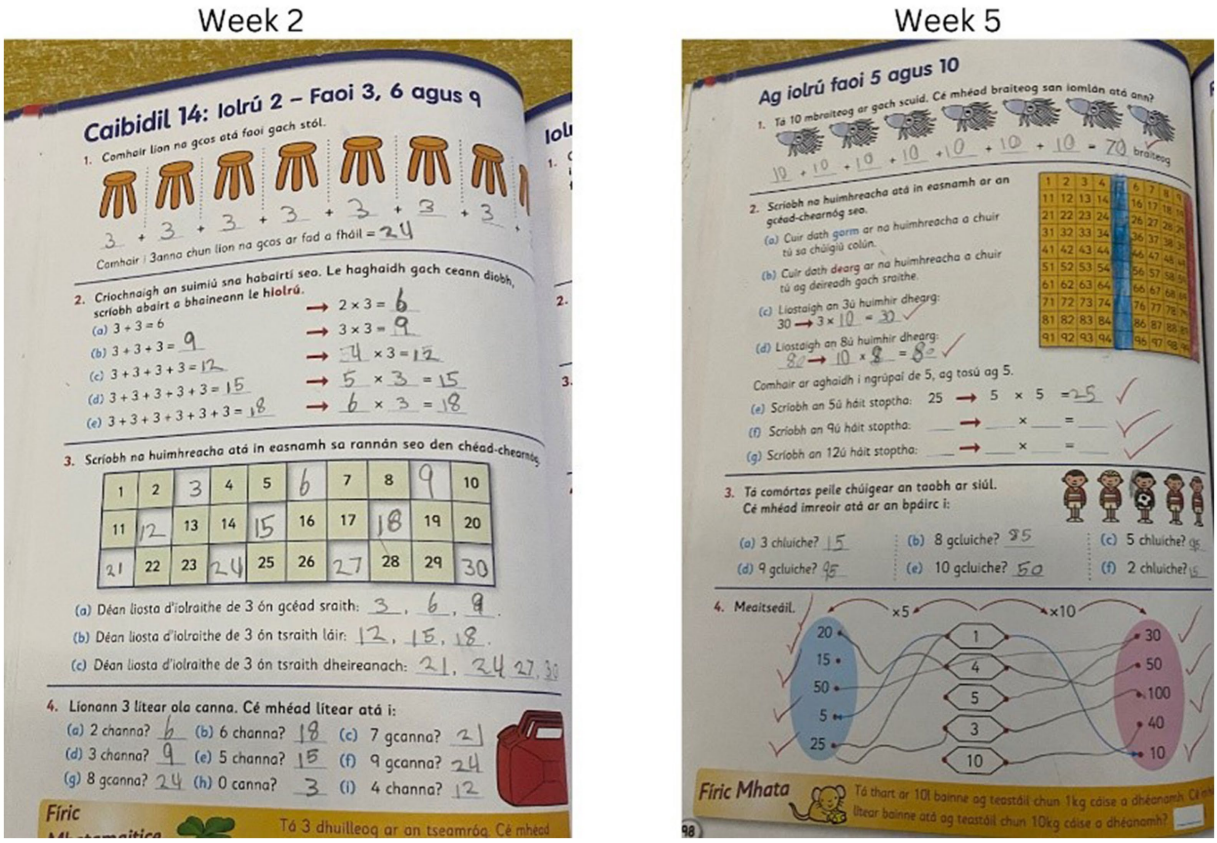


FIGURE 2
Sample of Saoirse's work.

but upon return to a topic had forgotten previously covered strategies and key language. Moreover, learning processes have been found to be successful only when the total cognitive load does not exceed the capacity of working memory (Lenz et al., 2024). Based on limited available research it is fair to speculate that these students' experience significant cognitive demand both during lessons and in standardized

TABLE 5 Participants results on the summative assessments.

| Participant | GLM result | RDA result | Order of completion |
|---|---|---|---|
| Aisling | 59% | 59% | GLM then RDA |
| Caoimhe | 70% | 52% | GLM then RDA |
| Jenny | 59% | 55% | RDA then GLM |
| Mikey | 24% | 28% | RDA then GLM |
| Saoirse | 34% | 41% | RDA then GLM |

assessments when they are operating in a second language (Abedi and Lord, 2001) and juggling their AEN (Genesee and Fortune, 2014).

Interestingly, it was noted during the lessons that the wording of questions was causing Aisling the most difficulty, but she performed well across both assessments. Her mathematical knowledge was evident in both. Mathematical anxiety was a factor within her AEN. Her lack of confidence was impacting her processing abilities (Lenz et al., 2024). However, the support during the lessons appears to have alleviated some of this anxiety, as evidenced by her results. The impact of the language adaptations overall was minimal on the results of the participants, however, there is evidence that some of them were effective in aiding understanding of some of the questions. For example, question four on both assessments required participants to add two sums of money €4.20 and 60c in GLM and 70c in the RDA. The cent amounts were displayed in coin form on both. The wording of the GLM question appears to have caused confusion for Jenny and Mikey who both subtracted the 60c on that paper. All participants used addition in the RDA. Mikey answered incorrectly in the RDA, but it was clear he used addition. The phrasing and structure in the RDA were at a BICS level while the structure of the GLM could be classified as CALPS (Cummins, 2000). Errors in calculations appeared to be an issue for all participants. It was evident throughout that while they understood what was being asked of them, mistakes were made while doing the operations. This highlighted the gaps in their mathematical competencies as was witnessed during the lessons stage. These gaps are likely because of limited language proficiency working as a barrier to accessing the mathematics curriculum (MacKenzie et al., 2022).

The similarity in the results of the GLM assessment and the RDA suggest that these changes had negligible impact. However, when the class teacher compared these results to the Christmas assessments it was revealed that there had been significant improvement. The median result increased from 41 to 59. This improvement suggests that the design principles implemented at lesson stage had a positive impact on the results of the participants. In comparison to the results of the Christmas assessments, the recent assessments are a more accurate representation of the participants' abilities. The class teacher mentioned 'I was disappointed at Christmas. I felt they knew more than what they got right' (22/3/24). Both the class teacher and the teacher-researcher believed the participants' scores were reflective of their abilities and in line with their progress during the lessons.

What remains under question is the impact of the CLIL setting on their mathematical competencies. The class teacher remarked 'I wonder if they would have scored higher if it was in English. I think Mikey might have' (22/3/24). Chance week caused us to question the role of CLIL above any other. The language was the primary barrier, yet it was unclear if the mathematical language or the Irish language were the biggest contributor. This is a question that has been presented across many studies and other researchers offer conflicting conclusions. Madrid and Pérez Cañado (2018) mentioned using the L1 to clarify concepts that are unclear in the L2 while teaching lessons. This would suggest that L1 is needed for retention of information and processing. Madrid and Pérez Cañado (2018) found that using the L1 to clarify complex concepts can sometimes improve student retention, a finding relevant to our observation of the challenges faced by participants in mastering mathematical terms in Irish. However, Genesee and Fortune (2014) also found that a below average group of L2 learners were no worse off than a group of below average learners in their L1. They found that low academic ability was no more of a barrier to immersion students than it is to monolingual learners. In fact, they found that 'low ability students can experience a net benefit from immersion' (Genesee and Fortune, 2014, p. 198). It is important to note that their findings stipulated that specialized support was required to support these students. Similarly, MacKenzie et al. (2022) also found that experiential, collaborative teaching was helpful in overcoming challenges with traditional print literacy. The findings from this research align with their conclusions. The class teacher reported that four of the five participants scored higher on these assessments than on their Christmas termly assessment. The language-responsive approach allowed for meaningful engagement with the material while also focusing on the language required at an appropriate level for the group. Further exploration is needed to examine the true impact of CLIL on mathematics learners with AEN in an immersion setting.

Due to staff shortages, the teacher-researcher was redeployed to a mainstream classroom during week five and was unavailable to attend all the scheduled lessons with the group. Consequently, they did not receive the language specific instruction or the opportunity to explore all the content in the small group setting. The effect of this is clear in their results in both assessments. All participants scored poorly in the time section of the assessments. Of the 12-time related questions, Aisling correctly answered two, Caoimhe and Jenny got four correct, while Mikey and Saoirse failed to answer any correctly. This section was also difficult to alter in terms of language. Four of the six questions remained unchanged as they were clock faces showing times. Support for students in this area was needed at lesson level and when this support was unavailable performance suffered. It became evident during this project that it is not always possible to adapt language or provide visual support, as was the case with the topic of chance, and consequently focus needs to be placed on teaching concepts and language in tandem (Ní Ríordáin, 2018).

## 7 Implications and conclusion

The language-adapted summative assessments had negligible impact on the results of the participants, however the findings highlighted that some adaptations were successful in improving the participants' ability to determine what was being asked of them. While this understanding became clearer, mathematical competency remained an issue. Consequently, this research points to summative assessment as being an ineffective method of assessing the competencies of students with AEN in IME settings. The language barriers that exist for these pupils because of their AEN and the lack of alternative methods of demonstrating understanding (e.g., the use

of concrete materials) make summative assessments too cognitively demanding and communicatively restricting for them. The design of language responsive lessons with explicit teaching of key terminology, an integrated approach to language and mathematics teaching, with a clear intent of reducing anxiety and cognitive load were more effective in supporting the participants to communicate their true proficiencies than the assessments. From a practice perspective, it is recommended that increased attention should be paid to planning accessible mathematics lessons for students with AEN in a CLIL context, perhaps through a more consistent application of CDFs as a pedagogical planning tool at the planning stage as well as better long-term planning, focusing on the need for repeated exposure to language at a cognitively appropriate level.

While the outcomes of this classroom-based research case study contribute to the scant research in the intersection between IME, mathematics and AEN, it cannot be denied that more pedagogically focused research and educator support is required. It is clear from the literature review undertaken here that many are convinced of the positive role that CLIL can play in developing content and language for diverse learners as well as the role that language-responsive planning, teaching, and learning and assessment has in IME contexts. However, empirically robust classroom-based research that illustrates how this can be effectively achieved in different contexts remains key to broadening the research horizon; in particular, how the plurilingual repertoires of learners can be leveraged to create deeper learning episodes (Meyer et al., 2018) that foster stronger bi/multilingual disciplinary literacies in mathematics through, for example, the careful scaffolding of CDFs over the short-, medium-, and long-term. CLIL research has developed a robust theoretical toolbox that is now waiting to be leveraged to support increasingly diverse learners. In Ireland, this need is especially pressing given that AEN learners in IME are a minority within a minority (Barnes, 2024); however, despite their status, they have a right to inclusive and equitable education and research, policy and practice must respond appropriately.

## Data availability statement

The datasets presented in this article are not readily available because participants did not consent to share data and sharing of data was not provided as part of the ethical approval. Requests to access the datasets should be directed to maire.niriordain@ucc.ie.

## Ethics statement

The studies involving humans were approved by School of Education Research Ethics Committee, University College Cork. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the individual(s), and minor(s)' legal guardian/next of kin, for the publication of any potentially identifiable images or data included in this article.

## Author contributions

MNíR: Conceptualization, Data curation, Methodology, Supervision, Writing – original draft, Writing – review & editing. CN: Writing – original draft, Writing – review & editing. MD: Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note



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