Language Barriers in Mathematics: Learning Challenges When Global Languages Replace Native Instruction

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Abstract

The teaching and learning process is a social practice that involves interactions between learners, teachers, and resources. These interactions are facilitated by various tools, especially tools for communication. The language of instruction is at the centre of this interaction and is the focus of this article. The article is conceptualised from the Tanzania context, where English is the medium of instruction, yet it is a second or third language to many learners. This article explores the phenomenon of English being the language of instruction in multilingual classrooms, posing opportunities and challenges in learning. Whereas fluency in English may aid the learning of mathematics, limited competence in English may hinder the learning of mathematics since learners must then simultaneously learn both English (the language of instruction) and mathematics. Additionally, the article discusses the differences in the meanings of various English terms when used in everyday English versus formal mathematical language. Suggestions for pedagogical practices to help learners develop English language competences without deferring the development of mathematical competences are provided.

Introduction

The process of learning mathematics involves both mental processes and social engagement, as described by Piaget (1972). The social element is the focus of the article, namely, how language mediates social interaction (Vygotsky, 1986). Whereas classroom interaction tends to be local, globalisation of education has influenced the language of instruction. For example, 47 countries globally use English medium instruction in secondary and university education (University of Leicester, 2023). About 40% of the world's population does not have access to education in the language they speak or understand (Global Education Monitoring Report Team, 2016). Learners of mathematics who are not native English speakers may struggle with the language, not only because (for some) it is not their first language, but also because English often carries discipline-specific meanings that might be confusing, even for native English speakers. Adding to this confusion is that the language of mathematics as a discipline differs from everyday language. Mathematics has its own register and syntax, communicated using symbols, figures, and numerals. Whilst the language of mathematics is often said to transcend cultural boundaries, this may only be achieved at advanced levels of mathematical practice. For students learning mathematics, classroom discourse must utilise both everyday language and formal mathematical language. This integration is pedagogical and requires teachers' competences in both the language of instruction and mathematical language. It also requires awareness of students' language backgrounds and cultural context since language and meaning are context-specific. This article explores these issues by expounding on the language of instruction and mathematical language. It is conceptualised in the Tanzanian context, where

English is the medium of instruction in secondary schools despite being the second and sometimes third language to many learners.

Language and learning

Learning theories can explain the educational process in multiple ways. From the theory of cognitive development of Jean Piaget (1972) and the sociocultural theory of cognitive development of Lev Vygotsky (1986), the learning process can be conceived as an interactive process involving multiple parties. For example, Piaget sees learning as dependent on the learner's age and interaction with the physical and social environment (Piaget, 1972; Taber, 2020). This interaction may lead to a cognitive conflict between learners' beliefs and the observed reality that must be resolved through equilibration or adaptation (Schunk, 2012). In mathematics learning, conflict may arise between the everyday language known to the learners and the formal mathematical language introduced in mathematics instruction. Putting more emphasis on social factors, Vygotsky argues that learning results from interactions between individual, interpersonal, and cultural factors (Bálint, 2023); it is a social process and an active construction of knowledge. This process uses various tools, including cultural objects, language, and institutions. Three tools influence learning, and each is coordinated by social interactions (Das, 2020). Language is one such critical tool through which learners not only communicate, but is also used to aid in thinking (Bálint, 2023; Vygotsky, 1986), even if not all thinking is verbal (Taber, 2020; Vygotsky, 1986).

This article discusses the role of one tool – language – in teaching and learning mathematics. To do this, I delve into the works of Vygotsky to explore how language is important in teaching and learning. This is followed by a discussion of the English language as one of the common mediums of instruction, and how it departs from subject-specific language, specifically mathematical language. Furthermore, I explore the mathematical language used to communicate mathematical concepts, its sociocultural roots, and ways of harmonising mathematics instruction and language.

The teaching and learning process is language-dependent, and sociocultural theories have especially articulated the role of language in the teaching and learning process. The works by Vygotsky are key in understanding how language as a tool is imperative in learning. From constructivism, active interaction (including conversing) is important in knowledge construction (Andrews, van Lieshout, & Kaudal, 2023). It is through listening to comprehend, speaking to explain, writing to communicate, and reading to extract meaning, that one may construct knowledge. This process is the active construction of knowledge, and language is a cognitive tool (Vygotsky, 1986). Writing (or note-taking) enhances memory, communication, and knowledge transfer, whilst reading aims to extract information from the text (Bálint, 2023); these tasks are naturally performed better in the language learners are more conversant with. Additionally, within the classroom context, learners are expected by their instructors to be active listeners and converse to share ideas (Taber, 2020).

Learners come to the classroom with pre-existing mathematical knowledge and concepts from their sociocultural background (Mosimege & Egara, 2022), upon which new knowledge is built. To construct new knowledge, the learning process in the classroom needs to be interactive, involving the sharing and exchanging of ideas, and learners need to be engaged in dialogue and conversation (Andrews et al., 2023; Chow & Jacobs, 2016). Chow and Jacobs (2016) add that oral language (especially for native English speakers) positively influences *fractions* learning outcomes of school-aged students. This interaction in the social context engages learners in the learning process and allows the development and construction of knowledge. At the heart of this learning process are the tools used to share such ideas (such as language, the focus of this article). The language of instruction in many countries (including Tanzania, where this article was conceptualised) is English. The following section explores English as an instructional language.

English as an instructional language

English is one of the most widely used languages to facilitate instruction worldwide (Macaro, Tian & Chu, 2020; Peng et al., 2020). It is either the first language for native English speakers, or, as the language of instruction in contexts where it is not the first language. In the latter case, learners may have one or more native languages besides English. For these learners, English might be their second, third, or even a further subsequent language. The term English Medium Instruction (EMI) denotes where English is used in the teaching and learning process to address multiple objectives. These include, first, developing English language competences through the teaching of other content areas in English (Jones, 2012) and, second, learning subject-specific language and content believed to be coded in English, rather than learners' first language (Macaro et al., 2020; Peng et al., 2020).

To ensure that curriculum developers give the English language appropriate attention, the policy documents usually state issues of medium of instruction (Jones, 2012). In sub-Saharan Africa, for example, many countries that were previously British colonies use English as their language of instruction in most or all of their educational levels (Berry, 1985; de Araujo, Roberts, Willey, & Zahner, 2018). However, in some countries (such as Tanzania, Kenya, and Rwanda), there is a policy emphasis on other languages, especially at lower levels of education (Kavenuke & Uwamahoro, 2017; Trudell & Piper, 2014). Although policies in Kenya guide the integration of learners' first languages in the early grades of primary school education, they have been accepted reluctantly, with many parents and teachers preferring Kiswahili and English (Trudell & Piper, 2014). Kiswahili is used in most primary schools in Tanzania, with few EMI schools. Pupils attending EMI schools are from high- and middle-income families, leading language of instruction to become an issue of social and economic classes (Njiku, 2019). However, at the secondary education level, the medium of instruction is English for all. Regardless at which level English becomes a compulsory language of instruction, it is a second or third language for many learners.

English being adopted as a second language and medium of instruction has received attention in the literature (Macaro et al., 2020; Peng et al., 2020; Piper, Zuilkowski, Kwayumba, & Oyanga, 2018). Similarly, the relationship between EMI and learning mathematics has been explored extensively in the literature (Makonye, 2019; Peng et al., 2020). There are mixed findings regarding the effects of EMI on mathematics instruction. For example, Peng et al. (2020) found a significant positive correlation between the language proficiency of native speakers and mathematics performance, but at least five other variables moderate these; similar arguments are presented by Cuevas (1984) and Makonye (2019). Peng et al. found that the relationship was not significant among learners whose native language is not English, after controlling for working memory and intelligence. Piper et al. (2018) explored the effects of learners' first language literacy on various subjects (including mathematics) in Kenya. They found that learners' first language negatively affected their mathematics learning. The adverse effects were attributed to the teachers being unfamiliar with the learners' first languages, leaving them ill-equipped to provide support in those languages.

Nevertheless, Macaro et al. (2020) and Peng et al. (2020) argue that native language (or that in which learners are more conversant) may be more helpful in learning mathematics concepts. The observation made by Piper et al. (2018) about the potential weakness of first language use among teachers emphasises another important consideration: teachers. Language challenges teachers or students face affect both, and, ultimately, the learning process (Makonye, 2019). In Tanzania, teachers and students have been reported to have limited language skills in English (Kavenuke & Uwamahoro, 2017) – the mandatory language of instruction in secondary schools. Thus, the debate and deliberations about the language of instruction should not be limited to whether students can learn various subjects in English, but also whether teachers have the necessary mastery of it.

Everyday language in the context of mathematics

Language is a crucial tool in the teaching and learning of mathematics, as it serves the purpose of communicating meaning and sharing ideas (Planas & Pimm, 2024), whereby the language of instruction (such as English) is used to communicate mathematical ideas or content. To achieve this, learners must possess mastery of the language of instruction. Also, classroom interaction tends to use 'everyday' English that learners need to be conversant with. Everyday English is, therefore, supposed to facilitate the communication of mathematical ideas and content (Jourdain & Sharma, 2016). English and mathematics content have a common vocabulary (as will soon be illustrated). In some studies, this intersection has been reported to be advantageous to learners, especially when they are native speakers (Chow & Jacobs, 2016; Jourdain & Sharma, 2016). This is because they do not have to struggle with learning the language of instruction. However, when learners must learn both the language of instruction and mathematics content simultaneously, this intersection becomes a problem (Jourdain & Sharma, 2016). The meanings of the same English words often differ between their use in everyday English language and mathematics (Makonye, 2019).

Some everyday English words hold different meanings when used within mathematical contexts. For example, when working on perimeters and areas in the study of *geometry*, Makonye (2019) points out that the word *area*, when used in everyday English, may refer to a geographical location. However, the same word, when used in mathematics, is precise and unambiguous: it refers to the size of a surface. Another confusing example is the use of the word *significant* (Jourdain & Sharma, 2016), which may infer different meanings in everyday English use compared to its formal definition within the context of *numbers* or *statistics*. While this discussion does not intend to produce an exhaustive list of such words, it is worth mentioning that there are mathematics register for the English language that carry specific mathematical meanings, that may indeed differ from their meanings in everyday English use.

Words such as *area, mean, operation,* and *element* are not unique to mathematics itself; instead, they are mathematical registers in the sense that some of their meanings belong to mathematics (Jourdain & Sharma, 2016), whilst also being used in everyday English. In mathematical contexts, these words carry precise meanings (Cuevas, 1984). When using mathematical registers, learners must use a language (such as English) whilst being aware that mathematical words may carry divergent meanings or mean different things to those within the context of everyday English. It is also important to note that some of the mathematics register is not used in everyday English, hence it is likely to be new, not only to English language learners, but also to native speakers. The language used for teaching (particularly mathematics) is different from everyday language; this is evident in textbooks that demand familiarity with not only mathematical register, but also grammatical patterns, presentation style, and argumentation

(Cuevas, 1984). As such, teachers must help their learners to develop competences in formal and written mathematical language from their fluent informal spoken language (Pimm & Keynes, 1994).

Mathematical language

Mathematical language (or, 'the language of mathematics', as it is sometimes referred to) can be interpreted in multiple ways, as suggested by Pimm and Keynes (1994): the spoken language of the mathematics classroom, mathematics register, the language of textbooks (including graphics and other modes of representation), and written symbolical forms. From this, it can be deduced that mathematical language consists of the symbols, expressions, graphics, vocabulary, and syntax used to communicate and think about mathematics. Also, the use of such symbols and graphics is culture-independent and, thus, language-independent. Hence, part of mathematical language is translingual, since some written elements (especially symbols and drawn elements, such as graphs) transfer consistently across languages (O'Halloran, 2015). Additionally, such elements aid thinking, whereby mathematical language becomes an intrapersonal form of communication (Sfard, 2008). Mathematics adopts multimodal representations, including symbolic and graphical methods of communication. Morgan (2021) and O'Halloran (2015) argue this multimodal nature of mathematics representation is more communication than a language. For example, Morgan argues that mathematics classrooms use specialised notations, diverse forms of visual images, nonverbal communication (such as gestures), technology, and written and spoken language.

In the sub-section *Everyday language in the context of mathematics* earlier, I discuss how mathematical language includes vocabulary common with everyday language, and how the mathematical meaning may differ from the meaning in everyday usage. Studies refer to this as the mathematics register. Various vocabulary (*odd, even, mean, mode, product, sum, difference, area*, and *chord*) (Makonye, 2019; Tanzania Institute of Education, 2021; Thompson & Chappell, 2007) are used in mathematics and everyday English use. One feature of these words is their specific meaning when used in mathematical contexts. Even in mathematics, some words (such as *median*) may have different meanings when used in various mathematical contexts (for example, *geometry* and *statistics*) (Thompson & Chappell, 2007). Thus, knowledge and understanding of the context of their uses is vital. For instance, in Tanzania, students encounter EMI from their first year of secondary school. At this stage, they must navigate multiple language nuances, such as distinguishing between colloquial phrases like 'to *round* the corner' and mathematical terms like 'to *round* off numbers' (Tanzania Institute of Education, 2023).

Symbolism is a key element of the mathematical language (O'Halloran, 2015). The symbols carry different meanings or signify some actions or operations. Basic symbols (such as $+$, $-$, $/$, $\times$, $\div$, $\leq$, and $\geq$) and complex or more abstract symbols (such as $\sum$, $\pm$, $\int$, $\sqrt{x}$, !, and ∞) are used to communicate mathematical meanings and operations. Numerals are also symbols that communicate quantity. Although not global, these mathematical elements communicate the same meaning consistently across cultures or languages (O'Halloran, 2015). This 'mathematical language' element supports the assumption by many researchers that mathematics should not be a problem for English language learners, by virtue of its translingual and transnational features (de Araujo et al., 2018). However, it is not simply the individual notations that communicate meaning in mathematics but their systematic organisation (O'Halloran, 2015).

Mathematical expressions are like phrases in everyday English; they are made of a logical construction of multiple written elements, such as numbers, letters, characters, annotations, and symbols. To comprehend what expressions aim to communicate, one must understand the meaning of each of the elements of which such expressions are composed (Chow & Ekholm, 2019). For example, mathematical expressions can be used to communicate formulae, involving single (such $A = \pi r^2$ for the area of a circle) or multiple terms (such as $A = 2\pi r^2 + 2\pi rh$ for the surface area of a closed cylinder). Expressions can be reorganised or rewritten by following mathematical rules; for example, using algebraic factorisation, the expression $2\pi r^2 + 2\pi rh$ can be rewritten as $2\pi r(r + h)$. From these rules, we have mathematical syntax (Leibowitz, 2016), namely, the rules of manipulating mathematical expressions without changing their basic form. Chow and Ekholm (2019) found that understanding and skill in word order and combination are stronger predictors of performance than register. Even when everyday English is used, it must 'sound' mathematical, adhering to syntaxial rules, such that decoding meaning from such language produces appropriate mathematical expressions.

Geometric images are commonly used in mathematics (O'Halloran, 2015) to communicate specific mathematical information. They can take many forms, such as figures of polygons, graphs of functions, or statistical representations. As discussed in the *Mathematical language* subsection, mathematical language allows for multimodal representation, as evidenced by the example of graphing a function (Planas & Pimm, 2024). As such, meanings conveyed through graphics, images, and diagrams, can also be expressed algebraically, and vice versa. In the same way, meanings expressed algebraically or graphically can be translated into text. This versatility is where the value of the mathematics register lies. For example, in third-year secondary mathematics textbooks (Tanzania Institute of Education, 2021), students are given a guided task of drawing the relation $R = \{(x,y):y \geq x^2 + 1 \text{ and } y < 5\}$ and they are required to determine its domain and range. Thus, students are expected to know what a 'relation', 'domain', and 'range' mean in a mathematical context, to navigate this problem successfully.

Cultural responsiveness toward mathematics learning

Students come to their classes with preconceived notions. These notions encompass mathematical ideas that were ethnographically developed among their peers, as well as concepts embedded within the language of their specific culture (Bálint, 2023; Vygotsky, 1986). Jourdain and Sharma (2016) give an example where a teacher defines a *sample* as ‘a subset of a population, chosen freely without any rule or any obvious bias,’ but one of the students thinks of the word *sample* as being ‘a small amount of something like blood to test …’ (p. 1). Such students might have had an opportunity to visit a health facility and witness vials of blood being drawn for tests, which were referred to as *samples*. This example illustrates how students come to class with preconceived language meanings imported from everyday contexts, which may conflict with learning mathematics if not well handled.

As an element of culture, language is the most fundamental cognitive tool that supports thinking (Vygotsky, 1986); hence, it is a resource for learning. In multilingual contexts such as Tanzania, exposure to local languages and Kiswahili should be followed by exposure to English. This approach can expand the horizons for conceptual learning, by bringing in language examples and artifacts from diverse cultural backgrounds (Bálint, 2023). John (1985) uses a comparison example between Chinese and Motswana students in Canada, where the former's fluency in English is lower than the latter, but the former's performance in mathematics is not impaired because of language challenges. John further explains that the Chinese students reported thinking in Chinese and then translating their solutions into English.

This example shows how cultural tools such as language are vital in learning, and how language is a thinking resource, as argued by Vygotsky (1986).

Everyday language may also carry mathematical meanings. Indeed, mathematical concepts are occasionally used in society without formal knowledge. These concepts are communicated culturally, with language being a key vehicle (Bálint, 2023). Learning mathematics requires negotiating between cultural and formal mathematical knowledge (Jourdain & Sharma, 2016). The former may be used as building blocks for (or prior knowledge upon which) reconceptualisation and new mathematical knowledge may be built. Also, cultural knowledge is useful; it finds value in the context within which it was constructed and used (Bálint, 2023), and so, formal mathematics may be used to extend the understanding of cultural mathematics knowledge.

Language is a cultural component that communicates mathematical meaning and acts as a source and cultural store of mathematical knowledge (Bálint, 2023). As such, learning mathematics must necessarily use language as a key resource for knowledge construction and reconstruction. The learners' first language, normally spoken at home or in society is rich in mathematical concepts, inherent in the daily societal knowledge. So, to use this knowledge effectively, mathematics classrooms may need to integrate the language learners use in their everyday lives (Jourdain & Sharma, 2016).

In multilingual classrooms (or where EMI is used when English is not the native language), evidence has shown that negotiating between English and other native languages is essential. For example, whereas the number 12 is ‘ten and two’ in Kiswahili – and similarly in Chinese (Kenney, 2005) – it is ‘twelve’ in English, having no ordered relationship with other numbers. Similar differences (even in English) may be observed across contexts or nations. Another example is the number 1200, which can be interpreted as ‘one thousand and two hundred’ in some contexts, and ‘twelve hundred’ in others. And then 400,000 whilst is ‘four hundred thousand’ in United Kingdom English, it is ‘four lakhs’ in Indian English. These language elements may find their way into textbooks, and when this happens, writers need to consider the context in which the books are to be used (Morgan, 2021). On this view, Morgan adds that in countries where more than one language is common, there needs to be a sense of awareness of the consequences of using some words or others.

The roles of teachers and students in mathematics classrooms are determined by culture, curriculum, and institutional expectations. These expectations govern who, what, and how to speak (Morgan, 2021). Notably, interactions inside the classroom will likely differ from those outside, with students interacting differently depending on whether the teacher is present or absent. Although English is mandated for communication within the school environment in Tanzania (Kavenuke & Uwamahoro, 2017), students may feel more comfortable conversing in another language (Jourdain & Sharma, 2016). Students' seemingly spontaneous preference for one language over the other is not simply limited to their fluency or the cultural knowledge coded in the language, but also its cognitive role in facilitating thinking (John, 1985; Vygotsky, 1986). Even when English is a native language, everyday English words familiar to learners serve as stepping stones to formal mathematical language (Jourdain & Sharma, 2016). Just as Morgan (2021) maintains that the content of the mathematics classroom is inseparable from the social relations of the classroom, similarly, the learning of mathematics cannot be separated from the context in which it happens. The language that learners use is a key element of this context. When mathematical learning is rooted in culture (including language), it is referred to as ethnomathematics. To facilitate the learning of ethnomathematics, the teaching and learning process needs to be in the learners' first language (Makonye, 2019). Ethnomathematics integrates students' knowledge as constructed from cultural backgrounds, making mathematics learning more relevant to the sociocultural lives of the learners.

Ethnomathematics is important in addressing culturally relevant mathematical elements, for example, with units of measurement (such as length, area, volume, or mass) (Septianawati, Turmudi, & Puspita, 2017). In addition, ethnomathematics may be specific to certain groups of people, such as urban versus rural communities, labour groups, and indigenous peoples or nations (Suprayo, Noto, & Subroto, 2019). Different cultures tend to maintain their deep-rooted cultural units of measurement, because they are both vehicles of communication, and tools for daily life activities (Septianawati et al., 2017). Sometimes, the use of analogy is required since it presents learners with concepts that are familiar to them from their cultural practices (Mukwambo, Ramasike, & Ngcoza, 2018). For example, in the local Tanzanian markets, ‘debe’ is a measurement derived from a common tin or plastic container equivalent to 20 litres. Yet, it can also be used to refer to 20 kilograms. In this context, one can observe that a container suitable for measuring units of volume is locally acceptable for measuring units of mass. Students come to class with this prior knowledge, which is instrumental to their subsequent learning (Sasidharan & Kareem, 2023). This suggests that the teaching of formal mathematical measurement may need to reconcile with these cultural measurement tools.

Language issues in mathematics classrooms

The use of EMI in the teaching and learning of mathematics serves two purposes. First: to help learners develop competences in the language of instruction for the sake of linguistic competences. Second: to develop the ability to decode mathematical concepts coded in curriculum documents (such as textbooks), many of which are written in English. Pedagogically, teachers need to be aware that they are teaching mathematics in English, to learners of English (Jourdain & Sharma, 2016). Though learning English has benefits and is worthwhile, it should not override the development of other competences. For this, de Araujo et al. (2018) argue that teachers should not defer mathematics learning for the sake of improving English language competences. To balance language learning and mathematics learning, teachers may need to adopt more flexible language uses, including codeswitching and translanguaging (Chronaki, Planas & Källberg, 2022; Gandara & Randall, 2019; Makonye, 2019). In Tanzania, the language of instruction in secondary schools is English. However, most students' first language is either Kiswahili or other local languages. In this context, Kavenuke and Uwamahoro (2017) advocated the consideration of codeswitching. This is because using EMI may play the role of silencing by limiting teacher-student and student-student classroom interaction.

In English medium mathematics classrooms where learners are less familiar with English, students must learn mathematics and English. This dual-content learning places a high cognitive load on the students. Since both are important, teachers must plan to help students develop competences in both areas. However, in the Tanzanian context, many teachers and students struggle to express themselves in English (Kavenuke & Uwamahoro, 2017). Consequently, classroom interaction becomes ineffective in developing mathematical competences. Learning results from interaction, and limited language competences inhibit the latter. Given that everyday English may differ from the English used in mathematics, the teaching of mathematics register to students is imperative (Jourdain & Sharma, 2016). Other scholars advocate that students should be given more time to process information, since they are learning both mathematics and English simultaneously (Clarkson, 2007; Meaney, 2006).

Assessment in mathematics utilises various methods and tools, such as classroom and national (or standardised) tests. Regardless of whether the assessment method is verbal or written, language remains a tool for conveying the assessment content and instructions. If students have limited competences in the language of instruction, they may fail to decode the information in the assessment tool. Also, if teachers and students have challenges expressing themselves in English, this may affect what teachers construct during test development, and how students communicate their responses to test items. This raises concerns about the validity of test results when mathematics is examined in a second language (Cuevas, 1984), namely, whether the results are reflective of, or moderated predominantly by, mathematics or language competences. For students who are not native English speakers, their performance in mathematics may be a function of having limited English language competences. Thus, the effects induced by the language used in assessment tools must be considered when interpreting assessment results.

Conclusion and recommendations

English is a global language used in many educational systems, either as the native language, or as the language of instruction. In EMI, English facilitates interaction between students and teachers, and policies in various countries mandate using EMI to develop English language competences. Students with good English language competences have been found to benefit from the learning process more than those with limited competences. In this article I have argued that, whilst everyday English shares common words with mathematics, they may have different meanings specific to mathematical concepts. I also observe that, whilst mathematics has its own set of language-related elements and rules for communicating mathematical concepts, some mathematical concepts are embedded within students' culture. To this end, I conclude that teachers be mindful of students' cultural background (especially their language) when teaching them mathematics. Teachers should strive to professionally and pedagogically negotiate between implementing any EMI policies and the development of students' mathematics competences. Research shows that students begin thinking and then interact in their native or local language, and then re-code their ideas into English. Since interaction is key to learning, teachers should seek to not inhibit interaction due to limitations in English language skills. Thus, the mathematics teaching and learning process should help students develop mathematical competences (including mathematical language) and the development of English language competences, all whilst considering students' sociocultural background.

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