BOLETIM GEPEM
Grupo de Estudos e Pesquisas em Educação Matemática

AI Generative for Inclusive Mathematics Education: Empowering Additional-Language Learners and Their Teachers in 21st-Century Classrooms

Jinos Nejad Mikailli[1]
Universidade Estadual Paulista - Unesp

Marcus Vinicius Maltempi[2]
Universidade Estadual Paulista - Unesp

ABSTRACT
With the dramatic increase in the number of refugees over the past decade, implementing a 21st-century education has presented numerous challenges for teaching and learning math in multilingual and multicultural environments. Additional-language learners (ALLs) often struggle not with mathematical reasoning itself but with the linguistic and cultural demands embedded in 21st-century pedagogy. This study investigates the potential of generative artificial intelligence (GenAI) to empower additional language learners in 21st-century math classes particularly in the light of United Nations 2030 Agenda for Sustainable Development, which aims to guarantee inclusive and equitable quality education for all learners. Drawing on current literature on GenAI in education and semi-structured expert interviews, the study synthesizes how Generative AI tools such as adaptive learning systems, and language-support tools, interactive tools, and analytics dashboards can align with 21st-century pedagogical goals and the "4C" competencies of creativity, critical thinking, communication, and collaboration. Findings indicate that AI-driven tools can enhance access to mathematical discourse, personalize learning pathways, foster inclusive participation when implemented with cultural and ethical sensitivity, and relieve teachers' workload while supporting more equitable instruction. However, the positive role of AI in 21st-century math classrooms for ALLs depends on strict human oversight, protection of learner data, sensitivity to local contexts, and institutional support for training and critical evaluation. The study examines how specific AI affordances relate to the linguistic and cultural challenges faced by ALLs, offering practical guidance for researchers, developers, and educators aiming to design inclusive, human-centered AI systems for mathematics education.
Keywords: AI in mathematics education; additional-language contexts; 21st-century skills (4cs); human-in-the-loop; inclusive education.

IA Generativa para uma Educação Matemática Inclusiva: Empoderando Estudantes de Língua Adicional e seus Professores em Salas de Aula do Século XXI

RESUMO

[1] Mestre em Educação Matemática pelo Programa de Pós-Graduação em Educação Matemática da Universidade Estadual Paulista (Unesp), Rio Claro, SP, Brasil. Endereço para correspondência: Av. 24A, 1515, Bela Vista, Rio Claro, SP, Brasil, 13506-900. ORCID: https://orcid.org/0009-0004-2813-4235. E-mail: jinos.mikailli@unesp.br.
[2] Livre-docente em Educação Matemática pela Universidade Estadual Paulista (Unesp). Professor do Programa de Pós-Graduação em Educação Matemática da Unesp, Rio Claro, SP, Brasil. Endereço para correspondência: Av. 24A, 1515, Bela Vista, Rio Claro, SP, Brasil, 13506-900. ORCID: https://orcid.org/0000-0001-5201-0348. E-mail: marcus.maltempi@unesp.br.

Com o aumento dramático do número de refugiados na última década, implementar uma educação do século XXI tem apresentado inúmeros desafios para o ensino e a aprendizagem de matemática em ambientes multilíngues e multiculturais. Aprendizes de línguas adicionais (ALLs) muitas vezes não têm dificuldades com o raciocínio matemático em si, mas sim com as exigências linguísticas e culturais incorporadas na pedagogia do século XXI. Este estudo investiga o potencial da inteligência artificial generativa (IAGen) para empoderar aprendizes de línguas adicionais em aulas de matemática do século XXI, particularmente à luz da Agenda 2030 das Nações Unidas para o Desenvolvimento Sustentável, que visa garantir uma educação de qualidade, inclusiva e equitativa para todos os aprendizes. Com base na literatura recente sobre IAGen na educação e em entrevistas semiestruturadas com especialistas, o estudo sintetiza de que maneira ferramentas de IA generativa — como sistemas de aprendizagem adaptativa, ferramentas de apoio linguístico, ferramentas interativas e painéis de análise (*analytics dashboards*) — podem se alinhar às metas pedagógicas do século XXI e às competências “4C”: criatividade, pensamento crítico, comunicação e colaboração. Os resultados indicam que ferramentas baseadas em IA podem ampliar o acesso ao discurso matemático, personalizar percursos de aprendizagem e fomentar uma participação inclusiva quando implementadas com sensibilidade cultural e ética, e aliviar a carga de trabalho dos professores, ao mesmo tempo que apoiam um ensino mais equitativo. No entanto, o papel positivo da IA em aulas de matemática do século XXI para ALLs depende de uma supervisão humana rigorosa, da proteção dos dados dos aprendizes, da sensibilidade aos contextos locais e do apoio institucional para formação e avaliação crítica. O estudo examina como determinadas *affordances* da IA se relacionam com os desafios linguísticos e culturais enfrentados pelos ALLs, oferecendo orientações práticas para pesquisadores, desenvolvedores e educadores que buscam projetar sistemas de IA inclusivos e centrados no humano para a educação matemática.
Palavras-chave: IA na educação matemática; contextos de língua adicional; competências do século xxi (4cs); human-in-the-loop; educação inclusiva.

IA generativa para una educación matemática inclusiva: empoderando a los estudiantes de lenguas adicionales y a sus docentes en aulas del siglo XXI

RESUMEN

Con el aumento dramático del número de personas refugiadas durante la última década, la implementación de la educación en el siglo XXI ha presentado numerosos desafíos para la enseñanza y el aprendizaje de las matemáticas en entornos multilingües y multiculturales. Los estudiantes que aprenden en una lengua adicional (ALLs) suelen enfrentar dificultades no en el razonamiento matemático en sí, sino en las demandas lingüísticas y culturales integradas en la pedagogía del siglo XXI. Este estudio examina el potencial de la inteligencia artificial generativa (IA-Gen) para empoderar a los aprendientes de lenguas adicionales en las clases de matemáticas del siglo XXI, particularmente a la luz de la Agenda 2030 de las Naciones Unidas para el Desarrollo Sostenible, que busca garantizar una educación inclusiva, equitativa y de calidad para todos los estudiantes. Basándose en la literatura reciente sobre IA-Gen en educación y en entrevistas semiestructuradas con expertos, el estudio sintetiza cómo herramientas de IA generativa —como los sistemas de aprendizaje adaptativo, las herramientas de apoyo lingüístico, las herramientas interactivas y los tableros analíticos— pueden alinearse con los objetivos pedagógicos del siglo XXI y con las competencias “4C”: creatividad, pensamiento crítico, comunicación y colaboración. Los hallazgos indican que las herramientas impulsadas por IA pueden ampliar el acceso al discurso matemático, personalizar las trayectorias de aprendizaje, fomentar una participación inclusiva cuando se implementan con sensibilidad cultural y ética, y aliviar la carga laboral del profesorado, al mismo tiempo que apoyan una enseñanza más equitativa. No obstante, el papel positivo de la IA en las clases de matemáticas del siglo XXI para ALLs depende de una estricta supervisión humana, de la protección de los datos de los estudiantes, de la sensibilidad a los contextos locales y del apoyo institucional para la capacitación y la evaluación crítica. El estudio analiza cómo las funcionalidades específicas de la IA se relacionan con los desafíos lingüísticos y culturales que enfrentan los ALLs, ofreciendo orientaciones prácticas para investigadores, desarrolladores y educadores que buscan diseñar sistemas de IA inclusivos y centrados en las personas para la educación matemática.
Palabras clave: IA en la educación matemática; contextos de lengua adicional; competencias del siglo xxi (4c); humano-en-el-circuito; educación inclusiva.

INTRODUCTION

The rapid integration of artificial intelligence (AI) into education is reshaping how mathematics is taught and learned, yet students who study mathematics in an additional language often remain at a disadvantage. Findings reveal that emerging generative AI tools, such as Large Language Models (LLMs), automatic translation, multilingual/real-time feedback generators, and personalized learning environments can reduce language load for learners, helping them understand teachers' instructions and feedback and communicate their own reasoning with more confidence while simultaneously reducing teachers' workload through automated content generation, assessment support, and routine administrative tasks. However, these benefits depend on human-centered implementation and teacher oversight to ensure transparency, equity, and ethical use (UNESCO, 2023).

Overview

The recent surge in global refugee movements has led to the formation of multilingual classrooms, where students from diverse linguistic and cultural backgrounds learn side by side. This has contributed to the global call for inclusive education as reflected in the 2030 Agenda for Sustainable Development Goal 4, a global education goal ensuring access to inclusive, lifelong learning that equips individuals with the knowledge and skills required to seize opportunities and take an active role in society (UN Dept. of Economic and Social Affairs, 2015). In addition, major educational organizations, like the National Council of Teachers of Mathematics (NCTM), have strengthened their focus on equity as a fundamental component of education and mathematics learning (NCTM, 2000). Therefore, research initiatives have been encouraged to explore how new technologies can address this global educational crisis.

The learner population addressed in this study reflects this reality. Throughout this paper, the term additional language learners (ALLs) in the mathematics classroom refers not only to refugee and immigrant students but also to anyone whose first language is different from the official language of instruction. These learners are often expected to participate in mathematics immediately, provide reasoning and justification for math tasks, even while they are still developing basic academic language. They need to read the questions, understand them, translate their wording into a suitable mathematical approach, apply the required process skills, and present the solution in a clear written form (Ellerton, 1996). They may arrive at the correct answer but be unable to explain their reasoning (Schleppegrell, 2007), or their wrong answer may reflect misinterpretation rather than an error (Alrø, 1996). In parallel, this creates a serious problem for teachers to provide curricula, instructional support, and feedback. To design effective programs, teachers need to be aware of students' strengths and needs across diverse linguistic and cultural backgrounds (NCTM, 2000). According to Skovsmose (2020), teaching and learning are inseparable and they are "features of the same integral process" (p. 239). Accordingly, this study examines challenges for both students and teachers, as barriers to learning are intrinsically bound up with constraints on teaching.

The study focuses on what we can learn from professional mathematics teachers with a long history of working with additional language learners. This exploratory study collected data through semi-structured in-depth interviews with three mathematics education experts who work closely with ALLs, each specializing in a different aspect of mathematics teaching, including cross-cultural teaching, emerging technologies in education, and mathematics education for multilingual learners. In addition to the expert interviews, this study employed a narrative literature review approach to map the challenges identified in mathematics education for multilingual learners and to align them with potential technological and AI-supported interventions. The interviews focused on (a) the challenges that additional language learners and their teachers face in 21st-century math classes, and (b) the strategies teachers currently apply to respond to them. Along with the interviews, a narrative review of recent studies was carried out to (c) map common challenges in multilingual mathematics education and to connect them with emerging technological and AI-based approaches. Guided by these objectives, the research is articulated through the following research questions:

1. What challenges do additional language learners and their teachers face in 21st-century mathematics classrooms?
2. What strategies do teachers currently use to address these challenges?
3. In what ways can generative AI-supported tools enhance learning outcomes for additional language learners and support their teachers?

The findings are not intended to prove AI works but to collect informed, experiencebased insights that could help the development of design principles that can guide the creation of applications aimed at supporting 21st-century math in an additional language.

LITERATURE REVIEW

21^{st}-century mathematics pedagogy and the 4Cs

Along with the emergence of Generation Z and rapid advancement in technology, evolving job requirements encourage schools to design curricula that emphasize knowledge application, collaboration, and self-regulated learning skills. (Roll, 2016). Therefore, education authorities and instructors are being called upon to equip students with the essential skills to meet the unique challenges of their future careers (NCTM, 1980; Mohr, 2017). Engelbrecht (2020) describes this big change in the education process as a shift from 'push' in the traditional approach, in which teachers have the role of know-it-all, to a student-centered 'pull approach,' where students can learn through interaction, collaboration, and communication with others. Engelbrecht (2020) quotes the idea of Vygotsky's theory, highlighting the critical role of communication and interaction as a "primary role in the construction of learning" and a way to gain "higher levels of understanding and achievement" (p. 835). Considering the interests of Gen Z in interaction and collaboration through digital technologies (Mohr, 2017) and the necessity of a shift in the focus of school mathematics to problem-solving (NCTM, 1980), the main objectives of 21st-century math classes have a focus on the development of four skills (4Cs), including critical thinking, creativity, collaboration, and communication.

Challenges in Terms of Linguistic Differences

Many researchers have (mis)characterized mathematics as a universal language, suggesting that anyone with math understanding can solve math problems regardless of the language they speak, while most mathematical tasks are not "language free" (Adoniou, 2014; I & Martinez, 2020; MULWA, 2015). Speaking of language-related issues in mathematics might make one think of only word problems to understand classroom instruction and math problems. Mathematical registers and polysemy, like 'meet' in "parallel lines never meet," could be what adds to the complexity of comprehending the meaning of words (Moschkovich, 2002; Gee, 1999). There might also be some mathematical concepts that learners have not learned in their home country or some terms that do not exist in their first language, which makes them soon fall behind in their math class (I & Martinez, 2020). An ALL explains her experience of early years of math class as "I'm still guessing what 'perform the operation' means when the teacher is erasing the board. So, I just stop listening and figure I can't do math" (Tran, 2005, as cited in Freeman, 2012, p. 3).

Other than math terminologies used in the field of mathematics, there are some mathematical notations or formats for conveying ideas that might vary across countries. For example, the calendar date is shown as ‘May 15, 2007’ or ‘5/15/2007’ in the US, while in Latin American countries it is written as ‘15 May 2007’ or ‘15/5/2007’. In Mexico, negative numbers may be written as –5 or with the negative sign placed above the numeral. In German mathematical notation, a dot (.) is used for multiplication, while in Iran, the traditional multiplication sign (X) is used in math textbooks (Lopez, 2008).

In addition, considering 21st-century skills, mathematical problems provide many real-world examples and require the students to understand math problems thoroughly. In many fields of study, readers can apply strategies such as skimming or inferring meaning from context to understand the message of the text without knowing the meaning of all the words. However, in mathematics, the meaning of the sentence or problem can change if the reader does not understand all of the words. “More” and “Less” are two of the most commonly used words in the early years of school that can be challenging for language learners when they are used in more linguistically complex forms. Both native and additional language learners can provide correct answers to simple questions like “Which is more, 10 or 13?”. However, as the instruction gets more complicated, like in ‘What number is 1 more than 5?’, “the second-language learners lagged well behind the first-language learners in achieving mastery of the meaning of 'more' and 'less' in a given context” (Jones, 1982, p. 276). The main reason for that is that students need to go beyond their vocabulary knowledge and determine the meaning by the context in which the terms are used.

Learners in 21st-century math classes are expected to comprehend and interpret word problems, follow complex instructions, and share their novel ideas with their classmates through collaboration and communication. It is also essential for them to understand their peers and the solutions they find, make some comments on them, and help one another to develop their ideas (Ellerton, 1996; Moschkovich, 2002). These tasks require a strong command of the language used in instruction, which makes language proficiency an essential skill for success in math. In an interview that Yoon (2013) conducted with ALLs, one student described the classroom’s unequal power dynamics:

> For us, we are more like audience, not the, how to say, the same level participant as them. So we listen to their lecture, listen to what they speak, but actually, even when we talk, we show some comments. So I think they’re more like the speakers, and we are more like the listeners (p. 68).

Yoon (2013) continues that those participants who have better language proficiency might feel superior to those with limited language skills. What adds to the complexity of math learning by language learners is that they are simultaneously learning a language and studying mathematics through that same language. (Adoniou, 2014; Akhter, 2025). They might get to the right answer but feel unable to explain their reasoning (Schleppegrell, 2007). This often leads to additional language learners being perceived as deficient rather than capable, despite their potential to achieve strong mathematical competence.

Challenges in Terms of Cultural Differences

In the context of education, language and culture are interconnected, and cultural values and norms significantly influence how students perceive mathematical concepts, engage in tasks, and approach problem-solving (I & Martinez, 2020; De Araujo, 2018; Cummins, 2000; Nasir, 2008; Wong, 2004). To promote educational equity, school systems should embed students' cultural backgrounds into the curriculum so that learning feels relevant and engaging (Cummins, 2000; Nasir, 2008; OECD, 2015).

Yoon (2008) believes that "the teachers' frustration was largely caused by their focus on the students' linguistic needs only" and "the issue of the students' cultural and social needs was not taken into consideration for their learning" (p. 497). Students in a multicultural setting might not have any problem with math, but with understanding the context of the problem, as they cannot relate to the context of math tasks for cultural relevance (De Araujo, 2018). Differences in measurement units, currencies, cultural occasions, geographical content, cultural values, gender norms, math gestures, and representations and names can be distracting for learners and might cause confusion in visualizing the problem and understanding the context. Jourdain (2016) provides an interesting example of a Mexican girl in an American classroom struggling with the culturally unfamiliar phrase "hanging streamers" in the context of a party. As streamers had never been used in parties in her culture, she recalled her knowledge of "knowing that a stream was a moving body of water" (p. 9). This is how she mistakenly related streamer to stream and tried to figure out how to measure stream.

Cultural differences are presented in prior educational experiences, communication styles, and conceptual frameworks (Akhter, 2025). While some countries emphasize memorization, others show more interest in more studentcentered methods, encouraging critical thinking and problem-solving (Leung, 2001). Unlike Japanese teachers that focus much on teaching math through critical thinking and collaboration, Wong (2004) quotes students' ideas about education in China as, "you just sit there listen to what teachers said" and "the tutors spoon feeding you, not so much on discussion" and in Malaysia as "as long as you study and memorize what you learn you can do well." Another Malaysian student claims that "before I came here...teacher will tell you everything and then you just read, memorize, and then go to the exam, that is all. Most of the students do not need to express our own opinion" (p. 158, 159).

Furthermore, problem strategies that are applied in different education systems might vary. I & Martinez (2020) brings an interesting example of a student called Sunni who had learned to solve quadratic equations by factoring in her home country, which was different from the common method used in the U.S. Sunni realized that her math teacher had marked her answers incorrect, even though they were actually correct. Even after Sunni tried to explain how she had solved the problems (with her limited knowledge of English), the math teacher insisted that she use only the method taught in class. These differences in problem-solving methods get worse when learners cannot explain their thinking process due to their language barriers. This may result in the devaluation of students' mathematical knowledge, as exemplified by Sunni's experience.

Different countries might prioritize certain mathematical skills based on cultural, societal, or economic needs. Learners respond to math tasks based on what they know, and their prior knowledge matters a lot in current learning (Hiebert, 2006). If students have not fully understood the foundational knowledge in their countries, this gap in understanding can create significant challenges in their educational journey.

Culture can also affect students' learning styles. Students from different cultures show different learning preferences and performances in class. The one from a culture with high assertiveness who values competition and directness might find it hard to participate in 21st-century education, which requires effective communication, involving active listening and collaboration. A student from a high in-group collectivism culture, which emphasizes group harmony, may struggle with the emphasis on individual creativity in the 21st century. The one with an individualistic culture, who gives priority to individual achievement and personal goals, could encounter difficulties with 21st-century education, which promotes collaboration and values group success. Learners from high power-distance cultures that accept hierarchical order without much questioning can have a hard time applying critical thinking, offering challenging ideas, and questioning one another. Female students from societies marked by significant gender inequality may fear of being judged for their viewpoints and might hesitate to participate in collaborations and communications. Adapting to a class that promotes equality might need additional support (Joy, 2009).

Educators should bridge these cultural gaps by promoting an environment that values different perspectives and encourages the development of 4C while respecting cultural backgrounds. Students must feel that their cultural identities are respected and integrated into the learning environment. Yoon (2008) explains his observation of a Korean student getting so excited about having the chance to find his voice to explain his culture to the class, which led to more participation and having a sense of belonging to the class. A Malaysian student in Australia is so satisfied, claiming that "when we discuss topic on cultural, they will ask, what do you think? They ask about Malaysia. They try to get me more involved in tutorial or lecture" (Wong, 2004, p. 164). The main reason to highlight cultural differences is to ensure that multicultural classes are free from cultural bias and that any potentially relevant cultural aspects are addressed before introducing math problems. Additionally, teachers can benefit from the presence of learners from different countries to provide more real-world math tasks that reflect the identities of the students to engage and motivate all (Yoon, 2008; Wong, 2004; De Araujo, 2018).

GenAI for Supporting ALLs in 21st-Century Mathematics

Artificial Intelligence provides a broad range of tools that can enhance teaching and learning for additional-language learners in 21st-century mathematics. Recent advancements in artificial intelligence have been remarkable, particularly the emergence of GenAI, an AI technology that uses conversational, human-language prompts to automatically generate responses and other content (UNESCO, 2023). It is important to note that many of these tools were not originally designed for education but have instead been adapted for learning purposes. GenAI can be employed in two main categories: learner-facing tools and teacher-facing tools. This supports what was mentioned earlier by Skovsmose (2020) about the intertwined nature of learning and teaching as these tools can enhance teaching effectiveness while simultaneously enriching students' learning experiences. The learner-facing tools represent a shift away from a 'one-size-fits-all' approach to learning, enabling students to learn at their own pace or tailor learning materials to their own interests and receive immediate feedback, which aligns with the objectives of the 21st-century math class. On the other hand, the teacher-facing tools help teachers to reduce their workload, get insights about students, and customize their teaching strategies in the classroom (Baker, 2019).

The integration of generative artificial intelligence into education offers significant potential to support additional language learners in 21st-century mathematics. This can be categorized into three main areas:

1. Language-support tools can generate and adapt learning materials by providing tasks and explanations in simplified language or bilingual formats. They can also provide real-time translations, paraphrasing, and automatic correction, and offer suggestions for clearer or more accurate wording (UNESCO, 2023).

2. Interactive learning tools can function as conversational partners for learners and stimulate human conversations by asking and answering questions via text, audio, or visual representations (Akhter, 2025). A generative AI-powered chatbot, also known as a conversational agent or virtual assistant, facilitates such interactions by asking and answering questions via text or audio. These tools have unlimited patience, time, and capability to respond to an unlimited number of requests, unlike human resources (Son, 2023). Innovations in AI chatbots, powered by large language models (LLMs), represent a leading category of interactive learning tools that can provide an interactive and dynamic learning experience to students.

3. Adaptive and personalized learning tools have the potential to bridge the gap for multilingual and multicultural learners by offering a personalized learning environment. These tools tailors education to students' pace, learning styles, needs, "age, attainment level, prior knowledge and personal relevance" by monitoring learner progress, task duration, and error patterns; recording performance in learner profiles; and identifying weaknesses through real-time customized feedback (Major, 2021, p. 1937). Since ALLs are not a homogeneous group of learners, adaptive learning tools can make sure that each student receives "the right level of challenge and support" (Onesi-Ozigagun et al., 2024) with precise intervention exactly where learners struggle.

Adaptive learning systems benefit from natural language processing (NLP) and speech recognition to simulate human conversation and operate effectively across varied linguistic and cultural settings (Akhter, 2025). GenAI in personalized learning provides tools to customize teaching content, including assignments, quizzes, and learning materials. They can also convert a text-based lesson into one with visual representations to consider all types of learners. Integrated automated grading tools with a scoring rubric enable immediate, real-time feedback on student performance and identify misunderstandings or challenges as they arise in large, diverse classrooms (Guettala, 2024; Davar, 2025).

In addition, students' outcomes and progress can be displayed in a userfriendly format through tools for predictive analytics on dashboards. Analytical information on educator-facing dashboards can help teachers track students' progress, mistakes, or weaknesses, and find those at risk of failing, while student-facing dashboard increases students' self-awareness by letting them keep track of their progress (Xin, 2021; Akhter, 2025; Guettala, 2024). Integration of AI in learning management systems (LMS) can allow implementation of an analytics dashboard (Alotaibi, 2024). It also serves as a virtual tutor, supporting the understanding of complex concepts by providing flipped classroom environments that allow additional language learners to personalize their pace and free up classroom time for teachers to address individual challenges instead of giving lectures (Davar, 2025). In addition, other AI-powered LMS tools, such as discussion forums and chatbots, can enhance student participation and achievement in hybrid learning environments (Alotaibi, 2024).

METHODOLOGY

The study employed an exploratory qualitative study using semi-structured interviews via video conference. The interviews included open-ended questions organized around both learner- and teacher-focused topics, targeting two key areas: (1) identifying the challenges that additional language learners and their teachers face in 21st-century math classes, and (2) the strategies teachers currently use to address these challenges. Participants were selected through purposeful sampling to capture diverse perspectives from mathematics educators who work closely with ALLs, each specializing in a different aspect of mathematics teaching, such as cross-cultural instruction, emerging educational technologies, and mathematics education for multilingual learners.

The study gathered insights from the first participant, an associate professor of mathematics education at Utah State University, who has been investigating instructional practices and emerging learning technologies that foster mathematical thinking in preschool and elementary education. She has extensive experience working with English as a Foreign Language (EFL) students, as well as elementary students over several years. She provided valuable insights during the interview, particularly in areas related to language learning challenges, strategies for younger learners, and the integration of technology into education. The second participant was an associate professor in the Department of Teacher Education at the Norwegian University of Science and Technology (NTNU). His research explores the role of both verbal and non-verbal language across cultures and how language is used as a resource for teaching and learning in diverse settings. The third participant holds a Ph.D. from the Department of Teaching and Learning at Stockholm University, specializing in mathematics education with a particular focus on multilingual students. Her research addresses the unique challenges and opportunities within mathematics learning environments for students who speak multiple languages, contributing valuable insights to the field of inclusive education. She has been teaching mathematics to students aged 7 to 12 at a Swedish school in Stockholm, where only the Swedish language is used. Her classroom includes students from more than twelve different nationalities, such as Bangladesh, Morocco, Iraq, Turkey, Somalia, Egypt, Colombia, Russia, Poland, Greece, Ukraine, Lebanon, and Kurdistan.

All participants were informed of the study's purpose and participated voluntarily. One-on-one video interviews (40–60 minutes) were audio-recorded, transcribed and analyzed. The interviews were conducted as conversations rather than strict Q&A sessions which is also known as semi-structured interviews, in-depth interviews, or flexibly structured interviews, allowing participants to express their thoughts more freely and enabling a co-construction of meaning between the interviewer and interviewee (Bogdan, 1997). The approach was chosen to elicit professional reflections and nuanced perspectives that are difficult to observe through quantitative or classroom-based research.

Following the interviews, a narrative literature review was conducted using academic databases, including Google Scholar, with keywords such as AI-driven education, personalized learning in mathematics education, and GenAI for SDG4, multilingual learners, cultural responsiveness. Findings from the literature were then mapped to the challenges identified during the interviews, enabling the study to (3) propose AI-supported strategies for inclusive and equitable mathematics teaching.

FINDINGS

Findings are organized around five interrelated categories and highlight both the challenges encountered and the coping strategies developed by teachers.

Linguistic Barriers and Polysemous Terminology

All participants described frequent misunderstandings of instructional phrases, symbolic conventions and polysemous terms such as mean, leave, table, field, function, and matrix—as well as confusion between similar symbols (e.g., · vs ×) and notational systems. One expert summarized the core condition as "*when there is no common* *language, there is no common understanding.*" He emphasized how learners' language limitations and their prior assumptions influence their interpretations of mathematical relationships. "*Language learners assume that the numbers grow bigger when they are raised to power. Therefore,* 3^{-2} *could be a mismatch for them*."

All participants noted that one of the main reasons for ALLs' limited participation in class activities is that they are simultaneously learning mathematics and the language of schooling. They described a range of compensatory strategies, including pre-teaching key vocabulary, using visual supports, gestures, slowing down explanations, and repeatedly checking comprehension. Teachers emphasized that while these strategies applied in the class offer some support, they are timeconsuming and often insufficient to ensure equitable engagement among all learners. The interview also underscores the importance of an ongoing teacher–parent communication for building trust and coordinating support for students—including clearly informing non-native parents about expected language-related difficulties— and highlights the risk when parents cannot communicate in the language of schooling.

Cultural Mediation of Mathematical Understanding

The insights reveal that teaching math in multilingual settings is not only about overcoming language barriers but also understanding and addressing the cultural issues that influence mathematical reasoning. One participant remarked, "*we should learn the language with the culture*" emphasizing that the interpretation of a word might vary across cultures. He also cited an example from Chilean classrooms where cultural naming traditions affected probability reasoning. When presented with the scenario "*Carlos and Maria have two children, and the second is a boy named Daniel*", local students assumed the first child could not be a girl, assigning a probability of zero to that outcome, because firstborn sons are commonly named after their fathers. Another participant underscored the importance of cultural sensitivity in teaching, stating that "*teachers should be aware of cultural differences, gender differences, and power dynamics and they should make sure that all voices are heard.*" She also observed that "*with Dual-Immersion programs, there is more cultural awareness… students understand one another better*." Similarly, a third participant noted that "*when students are asked to share something from their culture, it can help them feel a greater sense of belonging.*"

Educators, therefore, promoted asset-based approaches that value learners' linguistic and cultural backgrounds as strengths rather than deficits. To support such cases, teachers attempt to use culturally responsive problem contexts, and invite learners to share local or community-based examples to help them feel supported in class. While these practices are pedagogically valuable, they require careful planning.

Participation Anxiety and Classroom Management

Linguistic diversity also contributes to uneven participation and increased anxiety among students, as some additional-language learners show "*little confidence*" in responding to math questions. A participant noted that additional language learners are sometimes allowed to write their responses on mini whiteboards and participate in group reflections on common errors to create a low-pressure environment and encourage collaborative reasoning. "*In this situation, other students nag about why it takes him long to respond or when I listen to one, the rest start talking together… I am so pressured to tell them that they need to wait. Therefore, part of what I teach in the class is that we need to be patient and support one another. And that we are not all the same.*" Therefore, teachers who work with additional-language learners have to do couple of things at the same time: teach math, provide linguistic support, and help students understand and respect each other's differences, which greatly increases their workload.

Technology and AI

Technology was perceived both as a valuable resource and a persistent challenge. A participant reported structured access to iPads in Swedish schools to provide real-time feedback and immediate visualization of common errors. She has employed a creative color-coding system, marking major errors in red and minor ones in yellow. "*Students are given real-time feedback… they normally go for yellow first as they feel less stressed.*" Meanwhile, through collaborative feedback, they revisit incorrectly answered test items to examine whether errors arise from language-related difficulties or from misunderstanding the underlying mathematics. Drawing on her own experience as an additional-language learner, another participant emphasizes the value of translation and captioning tools in keeping all students engaged during collaborative tasks. "*AI and translation tools can help ensure that all group members are involved in collaborations and discussions.*"

All participants value technology/AI for translation, visibility of thinking, formative feedback, and multimodal presentation—while cautioning against overreliance on AI.

Constraints, Implementation Challenges, and Ethical Considerations

Reported barriers included teacher unpreparedness and resistance to change, time costs, classroom management during device login, network reliability, "*strict policies in some countries regarding Internet use and technology*," and insufficient staff training. A participant notes that "t*eachers need to figure out how to evaluate technology—whether as a tool to encourage collaboration or using it in traditional math teaching.*" Another participant stated that "s*ometimes new technology can limit old technologies or kill students' creativity.*" The other participant explained that "*the class sometimes gets noisy during the process of log-in… support for technical issues is essential.*" While all three emphasized the need for stronger evidence about specific tools in specific contexts, they also identified human-in-the-loop oversight, professional learning, and technical support as prerequisites for ethical, effective AI use.

The patterns identified across interviews reveal overlapping layers of challenge—linguistic, cultural, pedagogical, and logistical—that teachers navigate simultaneously. Building on the interview themes, a targeted narrative review of recent AI and GenAI literature in education and mathematics was conducted to identify categories of tools and affordances that directly respond to the documented challenges. This mapping operates as a needs analysis, aligning the requirements of ALLs and their teachers with AI-supported strategies and affordance, while assuming a human-in-the-loop model (Memarian & Doleck, 2024; UNESCO, 2023). This is synthesized in table 1.

TABLE 1 – Interview-Based Challenges and Aligned AI/GenAI-Supported Responses

Interview-based Challenge Theme	**Human / Pedagogical Responses Observed**	**Key AI / GenAI Tool Types**	**Intended Contribution for ALLs in Math**	**References**
Linguistic barriers (polysemy, academic registers, symbol mismatch, unfamiliar math vocabulary)	Pre-teaching vocabulary; visual supports; gestures; frequent meaning check; occasional use of L1	Multilingual/translation tools; captioning; term glossaries; text simplification; LLMs with multilingual prompts; text-tospeech; interactive tools supporting visuals.	Reduce linguistic load; clarify terminology and notation; provide sideby-side translations; simplify syntax; enable students to ask questions in	(UNESCO, 2023) (Davar, 2025)

			their home language while engaging with the same math tasks.	
Cultural (mis)alignment of tasks and representations	Inviting students' examples; explaining diverse methods; task adaptation	GenAI-supported content and task generators; interactive tools.	Support design of culturally relevant and responsive problems (names, units, contexts) that reflect learners' experiences.	(Walkingto n, 2024), (Davar, 2025)
Different learning paces and priorknowledge gaps; limited time for individual feedback	Differentiated explanations; extra help sessions; informal diagnostics	Adaptive/personali zed learning environments; intelligent tutoring systems; automated feedback; AIintegrated LMS with analytics.	Tailor tasks to individual progress; surface gaps between prior curricula and current content; provide dashboards for teachers to monitor progress and intervene early.	(Major, 2021), (OnesiOzigagun et al., 2024), *(Holmes, 2022), (Akhter, 2025),* (Alotaibi, 2024), (Xin, 2021), (Davar, 2025)
Participation anxiety and peer pressure; cultural background (power distance, gender roles, individualism/coll ectivism)	Norm-setting for respect; structured group work; targeted invitations to speak	AI-supported collaborative platforms; shared digital whiteboards; anonymous response systems; real-time translation in group chats; analytics on participation/turntaking.	Create low-risk participation channels; distribute speaking opportunities more equitably; support communication without exposing linguistic insecurity.	(Walkingto n, 2024), (Tapalova, 2022), (Son, 2023), (Guettala, 2024)
Limited awareness of learners' linguistic and cultural needs	Observation; manual tracking; individual follow-up.	Learning analytics dashboards integrating language and performance indicators.	Visualize who is struggling or excluded; flag patterns (e.g., persistent languagerelated errors); recommend targeted scaffolds.	(Alotaibi, 2024), (Xin, 2021), (Akhter, 2025), (Guettala, 2024)
High workload and toolevaluation burden for teachers	Selective tool use; reliance on intuition; reusing materials.	LLMs for lesson design, task differentiation, rubrics, feedback templates, documentation.	Reduce planning time; support evidenceinformed differentiation; free teacher capacity for high-value interactions.	(Davar, 2025), (Guettala, 2024), (Akhter, 2025)

Concerns about ethics, bias, and over-reliance	Critical discussion with students; cautious adoption; avoiding untrusted tools.	Human-in-the-loop governance of AI tools (teacher oversight, institutional guidelines, alignment with ethical frameworks)	Mitigate bias, stereotyping, and data misuse; reduce dependency; preserve teacher agency and responsibility.	(Unesco, 2023), (Memarian & Doleck, 2024)

Source: Prepared by the authors

Overall, the mapping suggests that technology and AI can meaningfully support multilingual mathematics learning only when guided by informed human decision-making. Human resources remain the central agents who select appropriate tools, interpret context, and mediate the cultural and linguistic differences that algorithms cannot fully capture. Therefore, this study's findings reaffirm the importance of a human-in-the-loop approach in which AI augments rather than automates pedagogical judgment (UNESCO, 2023; Memarian & Doleck, 2024).

DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

This study indicates that language barriers and cultural misalignment can lead to fragile participation by additional-language learners (ALLs), which can prevent the development of a genuine 21st-century (4C) mathematics classroom. The findings and conceptual mapping support the view that when used within a human-in-the-loop model, GenAI-supported tools can function as foundational teaching resources for equitable 4C-oriented mathematics teaching (Mikailli, 2025).

When an expert states that "*when there is no common language, there is no common understanding*," they are not pointing to a minor inconvenience but rather identifying a systemic design flaw in how mathematics is taught to linguistically diverse students. In response to this need, GenAI-supported language tools can lower language constraints by generating real-time translation, offering clearer explanations, and providing multi-modal representations under teacher supervision (UNESCO, 2023). This does not mean simplifying mathematics but providing a languageindependent pathway to understanding. Therefore, learners can fully understand instructions and mathematical problems, articulate their reasoning and refine their responses to math tasks, which aligns directly with communication and critical thinking goals. Moreover, with the emergence of multimodal applications, such as captioning and text-to-speech, applied in tools like intelligent personal assistants (IPAs), automatic transcribers, and note-taking apps, GenAI language-support tools can improve accessibility and collaboration among ALLs (Son, 2023).

Equal educational opportunities enabled by GenAI collaborative tools can address the expert's call to ensure that "*all voices are heard*" and that power is distributed equitably, with respect for diverse linguistic and cultural backgrounds. Chen (2023) highlights "fear of judgment from peers" as a key factor contributing to low confidence and limited engagement among students who "believe themselves to be behind." Human–machine interaction through interactive GenAI tools helps ALLs gain more confidence for active participation as they provide a comfortable environment to ask questions anonymously in any language without hesitation, anxiety, and the fear of being judged by their peers (Son, 2023). In addition, through collaboration and communication with peers using interactive tools, they are exposed to diverse perspectives, engage in critical thinking, and develop shared solutions. Learners can benefit from the outputs of math problems provided by LLMs to generate solution strategies to approach the problem, or to compare their reasoning with that of LLMs and to evaluate and correct the solutions provided by LLMs with their peers (Walkington, 2024; Son, 2023).

LLMs can be valuable tools for teachers in designing and adapting lesson plans by generating real-world math problems rooted in different cultural contexts to make lessons more relatable for students from diverse backgrounds and foster crosscultural learning through mathematics (Walkington, 2024; UNESCO, 2023). According to Walkington (2024), LLMs promote creative problem-solving by presenting diverse scenarios provided that teachers supply well-designed prompts (UNESCO, 2023). They also support collaborative learning, by encouraging students to rely on one another to complete tasks, often without becoming aware of language barriers. Walkington (2024) notes that students can co-construct creative personalized problems aligned with their interests with the help of LLMs. It believes that this can help students feel more valued and empowered. The professional judgment remains with the teacher, who selects, edits, and filters outputs. Therefore, GenAI can offer opportunities for teachers to relieve the pressure to spend more time providing additional support to additional language learners. This is how GenAI changes the role of educators to "coordinator" or even "mentor" instead of being responsible for making decisions for different aspects of the learning process under the traditional approach (Onesi-Ozigagun et al., 2024; Tapalova, 2022). In addition, Interactive tools create a shared communication network that strengthens teacher–parent collaboration and aligns support for students' learning.

Expert accounts reveal that group work often marginalizes additional language learners (ALLs), who are frequently perceived as 'slowing down' their peers. Personalized learning systems, which support customized and self-paced instruction can bridge cultural differences by providing a safe, non-judgmental environment for everyone to achieve equitable outcomes. Adaptive learning systems can provide personalized and interactive instruction by detecting students' errors and evaluating their abilities, adjusted according to learners' preferences and cultural context (Son, 2023; Major, 2021). While the students interact with adaptive tutors or intelligent tutoring systems (ITS), the system captures thousands of data points, including clicks, time on task, hint requests, correct responses, and revealed misconceptions and analyzes this data to decide the next content, activity, or quiz, creating and continually updating a personalized learning pathway (Holmes, 2022; Akhter, 2025). Adaptive tasks are assigned to each student based on their individual competence offering students a new page and information according to their correct/incorrect answers on the previous page. Students always receive automated real-time feedback to understand the rationale behind incorrect responses. AI-enhanced auto-assessment and grading systems further support personalized learning by offering greater accuracy, speed, and data security (Chiu, 2023; Fu, 2020). The analytics dashboard, provided by adaptive learning systems or the integration of AI and LMS, can offer a range of functions, including coursework completion, class participation and turntaking, exam attendance, and feedback on performance, strengths and weaknesses. These systems also analyze students' problem-solving styles, learning strategies, and error patterns (Furqon, 2023). This data can help educators group students strategically for collaborative tasks. The report received can also offer an understanding of students' academic growth for teachers and administrators to provide guidance where necessary (Zawacki-Richter, 2019) and track students' progress to make informal decisions to improve teaching strategies (Chiu, 2023). It also enables the system to separate genuine conceptual challenges from languagerelated obstacles and to select the most suitable interventions (Davar, 2025).

However, as participants repeatedly emphasized in the interviews, these benefits are highly conditional. UNESCO's 2023 Guidance for Generative AI in Education and Research cautions that GenAI deployment is constrained by serious ethical risks, including data privacy violations, teacher preparedness, algorithmic bias and cultural dominance, digital divides, and child protection concerns. One of the biggest challenges in the process of integration of AI in education is large amount of confidential information that AI requires about students, like students' learning style and capabilities. Therefore, sensitive personal information should be stored securely and accessed only by authorized personnel so as not to put students at risk of data misuse or identity exposure. Teachers' professional development, such as lack of training, resistance to change, and ongoing support is the other major issue. UNESCO also warns about technological infrastructure, such as access to resources and the digital divide. While technology and AI aim to provide equity in education, digital tools are unavailable in many schools due to inadequate infrastructure or limited funding. An additional concern is that some AI tools focus on providing quick answers rather than step-by-step explanations or might favor certain problem-solving methods and provide biased results. Furthermore, children should be watched while using the internet, their access to harmful pages should be restricted and they should be taught about the culture of proper use of the internet to find the information they need. For this purpose, schools need to put policies and everyone should be obliged to follow them.

This aligns with the human-centred AI frameworks proposed by UNESCO (2023), emphasizing augmentation rather than automation. In this study, interviewees consistently framed technology as valuable only when it supported—not replaced— the teacher's professional judgment. Future work should empirically test concrete implementations co-designed with teachers and ALLs to verify whether these AIsupported configurations genuinely enhance participation, understanding, and 4C competencies in diverse mathematics classrooms.

ACKNOWLEDGEMENTS

We would like to thank all participants for generously sharing their time, experience, and insight which made this study possible. This study was financed by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001 and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPQ) (2nd author - Grant 305264/2022-2).

REFERENCES

ADONIOU, M.; YI, Q. *Language, mathematics and English language learners*. The Australian Mathematics Teacher, v. 70, n. 3, p. 3–13, 2014.

AKHTER, E. *AI in the classroom: evaluating the effectiveness of intelligent tutoring systems for multilingual learners in secondary education*. ASRC Procedia: Global Perspectives in Science and Scholarship, v. 1, n. 1, p. 532–563, 2025.

ALOTAIBI, N. S. *The impact of AI and LMS integration on the future of higher education: opportunities, challenges, and strategies for transformation*. Sustainability, v. 16, n. 23, p. 10357, 2024.

ALRØ, H.; SKOVSMOSE, O. *On the right track*. For the Learning of Mathematics, v. 16, n. 1, p. 2–22, 1996.

BOGDAN, R.; BIKLEN, S. K. *Qualitative research for education*. 368. ed. Boston: Allyn & Bacon, 1997.

CHEN, C. *AI will transform teaching and learning: let's get it right*. Stanford University AI+ Education Summit, 7 jun. 2023. Disponível em: https://acceleratelearning.stanford.edu/story/ai-will-transform-teaching-and-learning-lets-get-it-right/. Acesso em: 11 nov. 2025.

CHIU, T. K. F. et al. *Systematic literature review on opportunities, challenges, and future research recommendations of artificial intelligence in education*. Computers and Education: Artificial Intelligence, v. 4, p. 100118, 2023.

CUMMINS, J. *Language, power, and pedagogy: bilingual children in the crossfire*. Clevedon: Multilingual Matters, 2000.

DE ARAUJO, Z. et al. *English learners in K–12 mathematics education: a review of the literature*. Review of Educational Research, v. 88, n. 6, p. 879–919, 2018.

DAVAR, N. F. et al. *AI chatbots in education: challenges and opportunities*. Information, v. 16, n. 3, p. 235, 2025.

ELLERTON, N. F.; CLARKSON, P. C. Language factors in mathematics teaching and learning. In: *INTERNATIONAL HANDBOOK OF MATHEMATICS EDUCATION*. 1996. p. 987–1033.

ENGELBRECHT, J.; LLINARES, S.; BORBA, M. C. *Transformation of the mathematics classroom with the internet*. ZDM – Mathematics Education, v. 52, n. 5, p. 825–841, 2020.

FREEMAN, B. *Using digital technologies to redress inequities for English language learners in the English-speaking mathematics classroom*. Computers & Education, v. 59, n. 1, p. 50–62, 2012.

FU, S. et al. *The affordances of AI-enabled automatic scoring applications on learners' continuous learning intention*. British Journal of Educational Technology, v. 51, n. 5, p. 1674–1692, 2020.

FURQON, M. et al. *The impact of learning management system (LMS) usage on students*. TEM Journal, v. 12, n. 2, 2023.

GEE, J. P. *An introduction to discourse analysis: theory and method*. London: Routledge, 1999.

GUETTALA, M. et al. *Generative artificial intelligence in education: advancing adaptive and personalized learning*. Acta Informatica Pragensia, v. 13, n. 3, p. 460–489, 2024.

HIEBERT, J.; CARPENTER, T. Learning and teaching. In: *HANDBOOK of research on mathematics teaching and learning*. [S. l.: s. n.], 2006. p. 65–97.

HOLMES, W.; TUOMI, I. *State of the art and practice in AI in education*. European Journal of Education, v. 57, n. 4, p. 542–570, 2022.

I, J.-Y.; MARTINEZ, R. *Teaching math for emergent bilinguals: building on culture, language, and identity*. Ames: Iowa State University Digital Press, 2020.

JONES, P. L. *Learning mathematics in a second language: a problem with more and less*. Educational Studies in Mathematics, v. 13, n. 3, p. 269–287, 1982.

JOURDAIN, L.; SHARMA, S. V. *Language challenges in mathematics education for English language learners*. Waikato Journal of Education, v. 21, n. 2, 2016.

JOY, S.; KOLB, D. A. *Are there cultural differences in learning style?* International Journal of Intercultural Relations, v. 33, n. 1, p. 69–85, 2009.

LEUNG, F. K. *In search of an East Asian identity in mathematics education*. Educational Studies in Mathematics, v. 47, p. 35–51, 2001.

LOPEZ, N. R. *Mathematical notation comparisons between US and Latin American countries*. 2008.

MAJOR, L. et al. *The effectiveness of technology-supported personalised learning*. British Journal of Educational Technology, v. 52, n. 5, p. 1935–1964, 2021.

MEMARIAN, B.; DOLECK, T. *Human-in-the-loop in artificial intelligence in education*. Computers in Human Behavior: Artificial Humans, v. 2, n. 1, 2024.

MIKAILLI, J. N. *Empowering additional language learners...*. 2025. Dissertação (Mestrado) — Universidade Estadual Paulista, 2025. Disponível em: https://hdl.handle.net/11449/296829. Acesso em: 18 nov. 2025.

MOHR, K. A.; MOHR, E. S. *Understanding Generation Z students...*. Journal on Empowering Teaching Excellence, v. 1, n. 1, p. 9–21, 2017.

MOSCHKOVICH, J. N. *A situated and sociocultural perspective on bilingual mathematics learners*. Mathematical Thinking and Learning, v. 4, n. 2-3, p. 189–212, 2002.

MULWA, E. C. *Difficulties encountered by students...*. Journal of Education and Practice, v. 6, n. 13, p. 27–37, 2015.

NASIR, N. I. S. et al. *Culture and mathematics in school*. Review of Research in Education, v. 32, n. 1, p. 187–240, 2008.

NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS. *An agenda for action*. Reston, VA: NCTM, 1980.

NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS. *Principles and standards for school mathematics*. Reston, VA: NCTM, 2000.

OECD. *Immigrant students at school*. Paris: OECD Publishing, 2015.

ONESI-OZIGAGUN, O. et al. *Revolutionizing education through AI*. International Journal of Applied Research in Social Sciences, v. 6, n. 4, p. 589–607, 2024.

ROLL, I.; WYLIE, R. *Evolution and revolution in artificial intelligence in education*. International Journal of Artificial Intelligence in Education, v. 26, p. 582–599, 2016.

SCHLEPPEGRELL, M. J. *The linguistic challenges of mathematics teaching and learning*. Reading & Writing Quarterly, v. 23, n. 2, p. 139–159, 2007.

SKOVSMOSE, O. *Critical mathematics education*. Cham: Springer, 2020.

SON, J. B. et al. *Artificial intelligence technologies and applications for language learning*. Journal of China Computer-Assisted Language Learning, 2023.

TAPALOVA, O.; ZHIYENBAYEVA, N. *Artificial intelligence in education*. Electronic Journal of e-Learning, v. 20, n. 5, p. 639–653, 2022.

WALKINGTON, C. *The implications of generative artificial intelligence for mathematics education*. 2024. Disponível em: https://doi.org/10.13140/RG.2.2.11192.15367. Acesso em: 11 nov. 2025.

WONG, J. K. K. *Are the learning styles of Asian international students culturally or contextually based?* International Education Journal, v. 4, n. 4, p. 154–166, 2004.

XIN, O. K.; SINGH, D. *Development of learning analytics dashboard*. International Journal of Advanced Computer Science and Applications, v. 12, n. 7, 2021.

YOON, B. *Uninvited guests*.... American Educational Research Journal, v. 45, n. 2, p. 495–522, 2008.

YOON, H. J. *Challenging the "non-native English speaker" identity*. Working Papers in Educational Linguistics, v. 28, n. 2, p. 55–75, 2013.

ZAWACKI-RICHTER, O. et al. *Systematic review of research on artificial intelligence*. International Journal of Educational Technology in Higher Education, v. 16, n. 1, p. 1–27, 2019.

UNESCO. *Guidance for generative AI in education and research*. Paris: UNESCO, 2023.