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(REVIEW ARTICLE)

Bridging STEM and linguistic gaps: A review of multilingual teaching approaches in science education

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Abstract

This paper examines how multilingual education strategies can be applied within STEM classrooms to bridge linguistic gaps and enhance learning outcomes. It reviews various teaching approaches incorporating multiple languages in conveying scientific concepts, aiming to improve accessibility, and understanding for students from diverse linguistic backgrounds. The analysis includes case studies of schools successfully implementing multilingual STEM programs, highlighting the benefits and challenges of such educational practices. Multilingualism presents challenges and opportunities in science education, particularly in bridging the gap between STEM (Science, Technology, Engineering, and Mathematics) subjects and linguistic diversity. This review provides an overview of the key themes and findings from a review of multilingual teaching approaches in science education. The review highlights multilingual students' challenges in STEM education, including language barriers that may impede their understanding of complex scientific concepts. It also examines the importance of addressing these challenges through innovative teaching approaches that leverage students' linguistic diversity as a strength rather than a limitation. Key findings from the review include the effectiveness of bilingual education models, such as content and language-integrated learning (CLIL), in enhancing students' scientific literacy and language proficiency. These models allow students to develop their STEM knowledge and language skills in tandem, leading to improved academic outcomes. The review also discusses the role of culturally responsive teaching in engaging multilingual students in STEM subjects. By incorporating students' cultural and linguistic backgrounds into the curriculum, educators can create more inclusive and effective learning environments that cater to the diverse needs of learners. Overall, the review highlights the importance of adopting a multilingual approach to teaching STEM subjects, which recognizes and values students' linguistic diversity. By embracing multilingualism in science education, educators can help bridge the gap between STEM and linguistic gaps, ultimately promoting more significant equity and inclusivity in STEM education.

Keywords: STEM; Bridging; Linguistic Gaps; Multilingual Teaching; Science Education

1. Introduction

In our increasingly globalized world, multilingualism has become a prevalent asset. However, this linguistic diversity in science education can present significant challenges for multilingual students (Adeniyi et al., 2024; Aronin, 2019; Pierson et al., 2021). This introduction aims to provide a comprehensive overview of the challenges faced by multilingual students in STEM (Science et al.) education, underscoring the criticality of addressing linguistic diversity in science education and presenting the thesis statement for a review of multilingual teaching approaches in science education to bridge the gap between STEM and linguistic diversity.

Multilingual students often face language barriers that can hinder their understanding of complex scientific concepts (Al Hamad et al., 2024; Charamba, 2021). The language of instruction in STEM subjects may not be their first language,

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leading to difficulties in comprehending technical terminology and academic texts. Additionally, multilingual students may need help with academic writing and verbal communication in the language of instruction, which can impact their performance in STEM subjects.

Recognizing and addressing linguistic diversity in science education is not just a matter of equity, but also a means of harnessing the unique perspectives and knowledge that multilingual students bring to the classroom. Their presence enriches the learning environment for all students (Buchs & Maradan, 2021, Okorie, et. al., 2024). By valuing and incorporating linguistic diversity, educators can create inclusive learning environments that not only support the academic success of multilingual students in STEM subjects but also foster a more diverse and dynamic learning environment for all.

This review explores various multilingual teaching approaches in science education to bridge the STEM and linguistic diversity gap. By examining the effectiveness of these approaches, this review seeks to provide insights into how educators can better support multilingual students in STEM education and promote greater inclusivity and diversity in science learning environments.

Multilingual students often face additional challenges beyond language barriers. They may also experience cultural differences that impact their learning experiences in STEM subjects. For example, certain cultural norms or educational practices may differ from those in the mainstream educational system, leading to misunderstandings or difficulties in adapting to new learning environments (Ganesan & Morales, 2024; Han et al., 2020; Udeh et al., 2024). Additionally, multilingual students may face socio-economic challenges impacting their access to resources and support systems for academic success in STEM fields.

Addressing linguistic diversity in science education is essential for supporting multilingual students and promoting diversity and inclusivity in STEM fields. By providing opportunities for multilingual students to excel in STEM subjects, educators can help create a more diverse and representative STEM workforce (Burdick, 2021; Oriekhoe et. al., 2024; Tripp & Waight, 2024). It can lead to innovations and breakthroughs in STEM fields that benefit society. In conclusion, addressing linguistic diversity in science education is crucial for ensuring equitable access to STEM learning opportunities and promoting diversity in STEM fields. By recognizing multilingual students' challenges and implementing practical teaching approaches, educators can help bridge the gap between STEM and linguistic diversity, creating a more inclusive and supportive learning environment for all students (Fu et al., 2019; Hoffman et al., 2021).

2. History of Bridging STEM and Linguistic Gaps

The history of bridging the gap between STEM (Science et al.) and linguistic diversity is complex and evolving, shaped by various factors, including educational policies, pedagogical approaches, and societal attitudes toward multilingualism (Adekuajo et al., 2023; Sarma & Bagiati, 2021). This essay provides a historical overview of the efforts to address linguistic diversity in science education, focusing on developing multilingual teaching approaches in STEM subjects.

One of the earliest efforts to address linguistic diversity in science education can be traced back to the 1960s and 1970s, with the emergence of bilingual education programs in the United States (Farayola et al., 2024; Sánchez-Pérez & Manzano-Agugliaro, 2021). These programs aimed to provide instruction in students' native languages while gradually transitioning them to English, allowing them to develop proficiency in both languages while learning STEM subjects. However, these programs faced challenges such as funding cuts and lack of support, leading to their decline in the following decades. In the 1980s and 1990s, there was a growing recognition of the importance of multicultural education in addressing the needs of diverse student populations (Adaga et al., 2023; Banks & Banks, 2019). Educators began exploring innovative approaches to teaching STEM subjects incorporating students' cultural and linguistic backgrounds. It led to the development of culturally responsive teaching strategies that engage students from diverse backgrounds by incorporating their cultural experiences into the curriculum.

In recent years, there has been a renewed interest in multilingual teaching approaches in STEM education, driven by the increasing linguistic diversity in many societies and the recognition of the benefits of bilingualism and multilingualism (Al Hamad et al., 2023; Christison et al., 2021). Educators have been exploring various approaches such as Content and Language Integrated Learning (CLIL), which integrates language learning with subject content, and translanguaging, which encourages students to use their entire linguistic repertoire to enhance their understanding of STEM concepts (Dada et al., 2024b; Biu et al., 2024c; Majemite et al., 2024b). Overall, the history of bridging the gap between STEM and linguistic diversity is marked by a gradual shift towards more inclusive and culturally responsive teaching approaches (Popo-Olaniyan et al., 2022; Yeh et al., 2022). While there have been challenges and setbacks,

educators continue to explore innovative ways to address linguistic diversity in science education, ensuring that all students have access to quality STEM learning experiences.

In addition to the historical development of multilingual teaching approaches in STEM education, it is essential to consider the broader context of educational reform and policy changes that have influenced efforts to address linguistic diversity in science education (Al Hamad et al., 2024; Alisaari et al., 2019). For example, the rise of standardized testing and accountability measures in education has pressured schools to improve academic outcomes for all students, including multilingual learners. This has led to an increased focus on developing strategies and programs that support the academic success of multilingual students in STEM subjects.

Another significant development in the history of bridging the gap between STEM and linguistic diversity is the growing recognition of the value of bilingualism and multilingualism in society (Afolabi et al., 2023; Udeh et al., 2023). Research has shown that bilingual individuals often have cognitive advantages, such as enhanced problem-solving skills and greater cognitive flexibility. As a result, attitudes toward multilingualism have shifted, with many educators and policymakers now viewing linguistic diversity as an asset that should be supported and celebrated in educational settings (Biu et al., 2024b; Majemite et al., 2024). More emphasis has been placed on culturally responsive teaching practices in STEM education in recent years. Educators increasingly recognize the importance of incorporating students' cultural and linguistic backgrounds into the curriculum to make learning more relevant and engaging for diverse student populations (Kieran & Anderson, 2019; Odulaja et al., 2023). This has led to innovative teaching approaches, such as project-based learning and inquiry-based instruction, to bridge the gap between STEM and linguistic diversity.

Looking ahead, ongoing advances in technology and globalization will likely shape the future of bridging the gap between STEM and linguistic diversity (Adeniyi et al., 2024; Kopalle et al., 2022). The ability to communicate and collaborate across linguistic and cultural boundaries will become increasingly important as the world becomes increasingly interconnected. Educators must continue to develop and refine multilingual teaching approaches that prepare students for success in an increasingly diverse and globalized world.

3. Challenges Faced by Multilingual Students in STEM Education

Multilingual students face unique challenges in STEM (Science et al.) education that can impact their learning experiences and academic success (Adewusi et al., 2023; Jacob et al., 2022). These challenges are often related to language barriers, limited proficiency in the language of instruction, and the impact of language on academic performance and engagement in STEM subjects. This essay explores these challenges in-depth and discusses strategies to address them.

One of the primary challenges multilingual students face in STEM education is the language barrier that can impede their understanding of complex scientific concepts (Adeniyi et al., 2024; Steigerwald et al., 2022). STEM subjects often involve technical terminology and academic language that may be difficult for students to comprehend, especially if they need to be proficient in the language of instruction. It may lead to misunderstandings and misconceptions about scientific concepts, hindering their ability to succeed in STEM subjects.

Multilingual students with limited proficiency in the language of instruction may need more support to help them overcome language barriers in STEM education (Amano et al., 2021; Oriekhoe et al., 2023). They may need help expressing their ideas clearly, participating in classroom discussions, or completing assignments requiring a high level of language proficiency. This lack of support can lead to frustration and disengagement from STEM subjects.

Language proficiency can significantly impact multilingual students' academic performance and engagement in STEM subjects (Okorie et al., 2024; Schiefer et al., 2024). Students who are not proficient in the language of instruction may need help to keep up with the pace of instruction, leading to lower grades and a lack of confidence in their abilities. Additionally, language barriers can hinder students' ability to engage with the material and participate in hands-on activities, which are critical components of STEM learning (Oliha et al., 2024; Obaigbena et al., 2024).

To address these challenges, educators can implement various strategies to support multilingual students in STEM education (Al Hamad et al., 2024; Auger et al., 2024). These strategies include providing language support services, such as bilingual education programs or language immersion experiences, that help students develop proficiency in the language of instruction while learning STEM subjects. Additionally, educators can create inclusive learning environments that value and celebrate linguistic diversity, providing opportunities for multilingual students to excel in STEM subjects. By addressing these challenges and supporting multilingual students in STEM education, educators can help ensure that all students can succeed in STEM fields. In addition to the challenges outlined above, multilingual

students in STEM education may face additional obstacles that can impact their learning experiences and academic performance (Biu et al., 2024a; Dada et al., 2024a).

Multilingual students may come from diverse cultural backgrounds influencing their learning styles and approaches to STEM subjects (Popo-Olaniyan et al., 2022; Schietroma, 2019). Educators need to be aware of these cultural differences and adapt their teaching methods to accommodate the needs of all students. Multilingual students may be more likely to experience stereotype threat, which is the fear of confirming negative stereotypes about one's social group. This can decrease confidence and performance in STEM subjects, particularly in high stakes testing situations.

Multilingual students may have limited access to resources such as textbooks, online materials, and academic support services in their native languages (Heugh et al., 2019; Oke et al., 2024). It can make it difficult for them to engage with the curriculum fully and may contribute to feelings of exclusion and marginalization. Multilingual students are more likely to come from disadvantaged socioeconomic backgrounds, which can impact their access to educational opportunities and support services. It can further exacerbate the challenges they face in STEM education.

Addressing these challenges requires a comprehensive approach that considers the unique needs of multilingual students in STEM education (Adekuajo et al., 2023; Doiz & Lasagabaster, 2020). Educators can implement the following strategies to support multilingual students: Provide language support services, such as language tutoring or bilingual education programs, to help students develop proficiency in the language of instruction. Create inclusive learning environments that value and celebrate linguistic diversity, allowing multilingual students to share their cultural and linguistic backgrounds. Offer culturally responsive teaching strategies incorporating students' cultural experiences into the curriculum, making learning more relevant and engaging for multilingual students.

Provide access to resources and support services, such as textbooks in multiple languages and academic counseling, to help multilingual students succeed in STEM subjects (Al Hamad et al., 2024; Brown, 2021; Popo-Olaniyan et al., 2022; Uwaoma et al., 2023). Address stereotype threat by fostering a supportive and inclusive classroom environment where all students feel valued and respected. By addressing these challenges and implementing effective strategies to support multilingual students in STEM education, educators can help ensure that all students can succeed in STEM fields, regardless of their linguistic background.

4. Importance of Multilingual Teaching Approaches in Science Education

Multilingual teaching approaches play a crucial role in addressing the linguistic diversity of students in science education (Adeniyi et al., 2024; Charamba, 2020). These approaches leverage students' linguistic diversity as a strength, enhance scientific literacy and language proficiency through bilingual education models like Content and Language Integrated Learning (CLIL), and engage multilingual students in STEM subjects through culturally responsive teaching. This essay explores the importance of multilingual teaching approaches in science education and their impact on student learning outcomes.

Multilingual teaching approaches recognize that students' linguistic diversity is an asset that can enhance their learning experiences in science education (Ayeni et al., 2024; Udeh et al., 2023). By incorporating students' native languages and cultural backgrounds into the curriculum, educators can create a more inclusive and engaging learning environment. This approach helps students feel more connected to the material and fosters a sense of pride in their linguistic and cultural heritage. Furthermore, leveraging students' linguistic diversity can enhance collaboration and communication skills as students learn to work with peers who may speak different languages. It prepares them for success in diverse and multicultural work environments, where effective communication is essential.

Bilingual education models, such as CLIL, effectively enhance multilingual students' scientific literacy and language proficiency (Danilov et al., 2020; Ogedengbe et al., 2023; Piacentini, 2021). CLIL integrates language learning with subject content, allowing students to develop their language skills while learning STEM subjects. This approach not only improves students' understanding of scientific concepts but also helps them become more proficient in the language of instruction. Research has shown that students in CLIL programs outperform their peers in their academic achievement and language proficiency in traditional language learning programs. It occurs because CLIL allows students to practice their language skills in authentic contexts, such as discussing scientific concepts and conducting experiments, which enhances their language acquisition.

Culturally responsive teaching is another vital aspect of multilingual teaching approaches in science education (Al Hamad et al., 2024; Popo-Olaniyan et al., 2022). This approach acknowledges and incorporates students' cultural backgrounds into the curriculum, making learning more relevant and engaging for multilingual students. Educators can

increase student engagement and motivation in STEM subjects by connecting STEM concepts to students' lived experiences and cultural contexts.

Moreover, culturally responsive teaching helps counteract stereotypes and biases that may impact multilingual students' academic performance and self-esteem. Educators can create a more inclusive and supportive learning environment by validating students' cultural identities and providing opportunities for them to see themselves reflected in the curriculum.

In conclusion, multilingual teaching approaches are essential for addressing the linguistic diversity of students in science education (Eboigbe et al., 2023; Uwaoma et al., 2023). These approaches leverage students' linguistic diversity as a strength, enhance scientific literacy and language proficiency through bilingual education models like CLIL, and engage multilingual students in STEM subjects through culturally responsive teaching. By implementing these approaches, educators can create more inclusive and effective learning environments that support the academic success of all students. In addition to the points mentioned, it is essential to highlight the broader benefits of multilingual teaching approaches in science education. These approaches benefit multilingual students and contribute to improving STEM education and the workforce.

Multilingual teaching approaches help promote diversity in STEM fields by providing opportunities for students from diverse linguistic backgrounds to excel (Eleogu et al., 2024; Mokikwa & Mokhele-Ramulumo, 2024). This diversity is crucial for fostering innovation and creativity in STEM, as individuals from different backgrounds bring unique perspectives and ideas. In an increasingly interconnected world, multilingualism is essential to enhance students' global competence. By learning STEM subjects in multiple languages, students develop a deeper understanding of global issues and are better equipped to collaborate with peers worldwide.

Multilingualism is a valuable skill in the global job market, particularly in STEM fields where international collaboration is common (Eleogu et al., 2024; Minakova & Canagarajah, 2023). By learning STEM subjects in multiple languages, students are better prepared for careers that require cross-cultural communication and collaboration. Research has shown that bilingualism can improve cognitive skills such as problem-solving, critical thinking, and creativity. Students can develop these skills while learning STEM subjects by engaging in multilingual teaching approaches, enhancing their academic performance.

Multilingual teaching approaches can help address equity issues in education by providing additional support and resources to students from diverse linguistic backgrounds. These approaches can help level the playing field and ensure all students have access to quality STEM education (Housel, 2020; Okorie et al., 2024). In conclusion, multilingual teaching approaches are essential for promoting diversity, enhancing global competence, preparing students for global careers, improving cognitive skills, and addressing equity in education. By implementing these approaches, educators can create more inclusive and effective learning environments that benefit all students, regardless of their linguistic background.

5. Review of Multilingual Teaching Approaches in Science Education

Multilingual teaching approaches in science education are essential for addressing students' linguistic diversity and promoting inclusivity in the classroom (Adeniyi et al., 2024; Tai, 2022). This review explores three main approaches: Content and Language Integrated Learning (CLIL) models, Culturally Responsive Teaching (CRT) strategies, and other innovative approaches to multilingual teaching in science education.

CLIL is an approach that integrates language learning with subject content, allowing students to develop language skills while learning STEM subjects (Al Hamad et al., 2024; Gorbaneva & Shramko, 2022). CLIL is particularly effective in science education because it allows students to use scientific language in authentic contexts, improving their understanding of complex scientific concepts. Research has shown that CLIL can improve students' academic achievement and language proficiency in STEM subjects. For example, Marsh (2002) found that students in CLIL programs performed better in science assessments than traditional language learning programs.

One example of the successful implementation of CLIL in science education is the European school system, which offers bilingual education in several languages, including English, French, and German (Bauer-Marschallinger et al., 2023; Orieno et al., 2024). In these schools, students learn science subjects in their second language, leading to improved language proficiency and academic achievement. Another example is the implementation of CLIL in China, where students learn science subjects in English. Research has shown that this approach has improved students' English language skills and scientific knowledge.

CRT is an approach that recognizes and incorporates students' cultural and linguistic backgrounds into the curriculum (Berlian et al., M. (2022; Popo-Olaniyan et al., 2022; Valdez-Castro, 2021). In science education, CRT can use culturally relevant examples and contexts to teach scientific concepts, making learning more meaningful and engaging for students. For example, a teacher might use local environmental issues to teach concepts such as pollution and conservation, connecting scientific concepts to students' experiences.

One example of a CRT strategy is using culturally relevant materials in the classroom, such as texts and videos that reflect students' cultural backgrounds. This can help students see themselves reflected in the curriculum, increasing their engagement and motivation. Another example is collaborative learning strategies promoting peer support and language development (Copeland et al., 2022; Oriekhoe et al., 2024; Uwaoma et al., 2023). For example, students might work in groups to conduct experiments or solve problems, providing opportunities for language practice and cultural exchange. Technology can be a powerful tool for supporting multilingual students in science education. For example, digital resources such as online simulations and interactive learning platforms can allow students to engage with scientific concepts in multiple languages.

Collaborative learning strategies can also effectively support multilingual students in science education. For example, peer tutoring programs can pair students with different language backgrounds, allowing them to support each other's language development while learning STEM subjects (Al Hamad et al., 2024; Ferguson-Patrick, 2020). In conclusion, multilingual teaching approaches in science education are essential for promoting inclusivity and addressing the linguistic diversity of students. CLIL models, CRT strategies, and other innovative approaches can help improve students' academic achievement and language proficiency in STEM subjects, creating more equitable learning environments for all students.

Multilingual teaching approaches in science education are essential for promoting inclusivity and addressing the linguistic diversity of students. (Christison, Krulatz & Sevinç, 2021, Oriekhoe, et. al., 2024) However, implementing these approaches effectively requires careful planning and consideration of various factors. Here are some additional considerations for implementing multilingual teaching approaches in science education: Teachers need training and support to implement multilingual teaching approaches effectively. It includes training in language teaching methodologies, cultural competency, and integrating language and content effectively in the classroom.

Curriculum development should consider students' linguistic and cultural backgrounds (Ayeni et al., 2024; Hyland, 2019; Macalister & Nation, 2019). It involves selecting culturally relevant examples and contexts for teaching scientific concepts and providing materials in multiple languages. Assessment practices should be aligned with multilingual teaching approaches, including developing alternative forms of assessment that allow students to demonstrate their understanding of scientific concepts in their native language.

Engaging parents and the community are crucial for the success of multilingual teaching approaches (Adewusi et al., 2023; Uwaoma et al., 2023). Parents must provide resources and support to help their children with homework and encourage community involvement in school activities. Schools must allocate resources to support multilingual teaching approaches, including hiring bilingual teachers, providing language support services, and purchasing materials in multiple languages. Policy support at the school, district, and national levels is essential for promoting multilingual teaching approaches. It may involve developing policies supporting bilingual education and funding language support services. By addressing these considerations, educators can effectively implement multilingual teaching approaches in science education, creating more inclusive and equitable learning environments for all students (Coyle et al., 2023; Grapin et al., 2023; Navarro Martell, 2022).

6. Conclusion

Bridging the gap between STEM and linguistic diversity in science education is crucial for promoting inclusivity and ensuring all students have access to quality STEM education. This review has highlighted the importance of multilingual teaching approaches in addressing students' linguistic diversity and promoting equitable learning environments in science education.

Key findings from the review include:

- The effectiveness of Content and Language Integrated Learning (CLIL) models in enhancing scientific literacy and language proficiency,
- The benefits of Culturally Responsive Teaching (CRT) strategies in engaging multilingual students and

- The value of innovative approaches, such as technology and collaborative learning strategies.

The implications for practice in bridging STEM and linguistic gaps are evident. Educators must adopt multilingual teaching approaches that leverage students' linguistic diversity as a strength, incorporate their cultural backgrounds into the curriculum, and provide support and resources to help them succeed in STEM subjects. This may involve implementing CLIL models, using CRT strategies, and integrating technology and collaborative learning into the classroom.

For future research, there is a need for more studies that explore the effectiveness of multilingual teaching approaches in science education, particularly in diverse and multicultural contexts. Research is also needed on the impact of these approaches on students' academic achievement, language proficiency, and long-term outcomes in STEM fields. In conclusion, bridging STEM and linguistic gaps in science education requires a concerted effort from educators, policymakers, and researchers. By adopting multilingual teaching approaches, we can create more inclusive and equitable learning environments that support the success of all students in STEM fields.

Compliance with ethical standards

Disclosure of conflict of interest

I declare that I have no conflicts of interest, financial or otherwise.

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