International Education Trend Issues
Volume 2, Number 2, 2024
https://ijble.com/index.php/ieti

Navigating Language Diversity In Multilingual Stem Classrooms: Strategies For Inclusive Education

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ABSTRACT
In multilingual STEM classrooms, language diversity presents challenges and opportunities for inclusivity. This study examines the impact of language diversity on STEM education, emphasizing its relevance in a globalized context. By employing a mixed-methods approach, including surveys and interviews with students, educators, and administrators, we identify patterns in the interplay between language diversity and inclusive education. Preliminary findings highlight challenges such as communication barriers and opportunities for enriched problem-solving. The discussion emphasizes recognizing linguistic diversity as an asset and suggests strategies to address barriers, advocating for a supportive, inclusive classroom. Implications for educators, policymakers, and researchers underscore leveraging linguistic diversity as a strength, with recommendations including professional development, integrating diverse perspectives into STEM materials, and implementing inclusive language policies for a more equitable STEM education landscape.

Keywords:
Multilingual STEM classrooms, Language diversity, Inclusivity, STEM education

INTRODUCTION

This study explores the intricate dynamics of multilingual STEM classrooms, emphasizing the profound influence of linguistic diversity on learners' experiences and performance (Charamba & Zano, 2019). The coexistence of multiple languages presents formidable challenges in communication, comprehension, and knowledge acquisition (PanSALB, 2000). Aligned with the core tenets of multilingualism, our investigation explores language proficiency and usage across diverse contexts (European Commission, 2007; Chibaka, 2018; Nosilela, 2019).

Our critical assessment of linguistic dynamics within multilingual STEM classrooms aims to refine educational methodologies and advance inclusivity for learners with diverse linguistic backgrounds. Emphasizing the pivotal role of family-school relationships in supporting multilingual learners (Đurišić & Bunijevac, 2017), we introduce translanguaging as a transformative pedagogical approach leveraging learners' linguistic resources for inclusive STEM education (Charamba & Zano, 2019). Drawing insights from our extensive teaching experience in South Africa's multilingual classrooms, we underscore the prevalence of translanguaging practices and the intricate language choices in STEM instruction.

Despite the emphasis on additive bilingualism and the cultivation of all eleven official languages in the South African Language in Education Policy (1997), English predominates in STEM classrooms, raising questions about the equilibrium between promoting indigenous languages and the practical needs of a multilingual instructional milieu.

The paper concludes by delving into the dynamics of translanguaging within STEM classrooms, addressing the gap between advocating for multilingualism and the dominance of English. Common practices, such as code-switching, are acknowledged, and the study aims to contribute meaningfully to the discourse on the benefits and implications of multilingualism in STEM education.

Literature Review

The rapid increase in South African STEM field enrollment, from 160,802 in 2015 to 263,721 in 2017 (Nemadziva et al., 2023), necessitates adaptable pedagogy (Smith & White, 2019). This growth, while promising, poses a dual challenge in supporting English Language Learners (ELL) (Hoffman et al., 2021), especially given the complexities of accommodating diverse linguistic backgrounds (Makoni, 2016) and striking a balance between language and content (Banegas, 2012). Against this backdrop, researchers explore translanguaging, the dynamic use of multiple languages for communication and meaning (Nicolarakis & Mitchell, 2023). This literature review comprehensively examines the impact of translanguaging on educational experiences, achievements, and engagement in multilingual STEM classrooms, critically analyzing its evolution and practical application (Song et al., 2022).

This review delves into the impact of translanguaging on educational experiences and achievements, specifically for English Language ELLs, amid the surge in South African STEM enrollment. Providing readers with a clear understanding of the current state of knowledge, the review articulates our study's contribution to the field, addressing a critical gap and positioning translanguaging as a potential solution to challenges arising from STEM enrolment growth (Ntuli, 2019). The evolution of translanguaging, traced from understanding learners' perspectives to becoming a pedagogical tool in multilingual STEM classrooms (Arendse, 2022), is framed as a natural progression, emphasizing the necessity for an in-depth exploration of translanguaging's impact on educational outcomes within English-dominant STEM classrooms.

Within the South African STEM education landscape, translanguaging strategically emerges as a response to challenges from English language dominance (Sembiante & Tian, 2020). The review comprehensively analyzes specific instances and scholarly studies, shedding light on the intricate challenges faced by learners proficient in their native languages. Tracing the historical evolution of translanguaging establishes a connection between this linguistic phenomenon and the challenges encountered within the South African STEM education system.

Various challenges faced by learners proficient in native languages within STEM education are highlighted. Studies, such as those by García (2009), emphasize obstacles stemming from English-dominated instruction in STEM fields. According to Tripp & Waight (2024), learners proficient in native languages often grapple with complex scientific concepts, hindering effective learning experiences. Makoni's (2016) work illuminates the scarcity of educational resources available in native languages within the STEM field, meaning that learners with proficiency in these languages may lack access to essential materials crucial for understanding STEM subjects.

Pierson et al. (2021) discuss assessment disparities faced by native language speakers in STEM. Assessments designed and administered in English create a language disparity that can impact accurate evaluation, hindering academic performance. In STEM classrooms where English dominates, learners proficient in native languages might face limited opportunities for active participation and engagement, as highlighted by studies similar to those of Probyn (2006). This limitation significantly impacts their overall learning experience.

Blackledge and Creese's work (2017) delves into the cultural and linguistic biases present in STEM content. Materials carrying such biases pose challenges for learners with diverse linguistic backgrounds, making it difficult for them to relate to or fully grasp the material, ultimately hampering academic achievement. These instances underscore the intricate and interconnected nature of challenges that learners proficient in native languages may encounter within STEM education.

This nuanced understanding of challenges serves as a foundational element, setting the stage for our study's exploration of practical solutions. In doing so, the review seeks to bridge the gap between theory and practice, presenting concrete and effective strategies to enhance educational experiences and outcomes for learners grappling with linguistic challenges within the South African STEM context. To initiate this multifaceted approach, a focus on the development and provision of multilingual instructional materials, the implementation of language-responsive pedagogy, and comprehensive training programs for STEM educators are imperative (Ganesan & Morales, 2022; Harper & Kayumoya, 2023; Alford & Kettle, 2020). Adapting assessments, establishing peer support programs, conducting STEM outreach programs, developing culturally relevant content, ensuring community involvement, leveraging technology, and continuous research and evaluation further contribute to creating a more inclusive and supportive South African STEM education system (Yerrick & Kearney, 2022). Through these strategies, South African STEM education can evolve into a system that caters to the linguistic diversity of learners, ultimately enhancing their educational experiences and outcomes.

Theoretical Framework

This study is anchored in a cognitive-social constructivist learning model, synthesizing key insights from prominent scholars such as Piaget, Vygotsky, and other esteemed constructivist theorists. Grounded in the premise that learning is a dynamic interplay between internal cognitive processes and external social interactions (Piaget, 1971; Vygotsky & Cole, 1978), our theoretical framework aims to provide a nuanced understanding of how multilingual learners navigate the complex landscape of STEM education.

Jean Piaget's constructivism serves as the foundational cornerstone, proposing that learners actively construct knowledge by assimilating and adjusting mental frameworks (Piaget, 1936). In the multilingual context of STEM education, learners' diverse linguistic backgrounds are regarded as a rich reservoir of prior knowledge, offering a scaffold for comprehending novel concepts (Cummins et al., 2005). This perspective positions linguistic diversity as an asset, contributing to the creation of a supportive learning environment.

Vygotsky's sociocultural theory seamlessly complements Piaget's constructivism by highlighting the pivotal role of social interactions and cultural tools in the learning process (Vygotsky, 1978). For multilingual learners shaped by diverse linguistic and cultural milieus, their social context significantly influences cognitive development. The zone of proximal development becomes crucial in the context of STEM education, emphasizing the importance of scaffolding to bridge the gap between learners' current capabilities and their potential for autonomous learning (Vygotsky & Cole, 1978). In STEM classrooms, scaffolding plays a pivotal role in facilitating multilingual learners' language acquisition and conceptual comprehension. Recognizing the varied multilingual literacies among learners becomes integral, enhancing their mastery of international languages, such as English, and providing access to socio-economic discourse (Martínez-Álvarez & Ghiso, 2017). The preservation and leveraging of native languages are emphasized for their role in strengthening learners' ability to construct meaning and grasp intricate STEM concepts (Lin, 2006).

Piaget's concept of equilibration assumes significance within this framework, shedding light on how learners adjust cognitive frameworks when confronted with novel information. Cognitive equilibrium, derived from equilibration, empowers multilingual learners to reconcile discrepancies within their existing knowledge frameworks (Inhelder & Piaget, 1958). In the multilingual context, equilibration plays a pivotal role in integrating new STEM knowledge with diverse linguistic backgrounds, fostering a profound comprehension of concepts, and promoting balanced cognitive development.

In this regard, our theoretical framework intricately weaves together the constructs of Piaget's constructivism, Vygotsky's sociocultural theory, and the inherent value of multilingual literacies. This synthesis offers a comprehensive understanding of how multilingual learners actively engage in STEM education. Therefore, by acknowledging the interplay of internal cognitive processes and external social interactions, educators are equipped to deploy effective strategies that empower multilingual learners, facilitating meaningful knowledge construction and fostering academic excellence in STEM subjects.

METHOD

This study embraces a qualitative methodology, specifically adopting an intrinsic case study design following the recommendations of Yin (2018). The primary objective is to extract valuable insights into language practices within multilingual STEM classrooms and understand their impact on learners' conceptual learning. The intrinsic case study design facilitates a comprehensive exploration of four specific cases involving STEM educators from South Africa. Aligned with Creswell and Creswell's (2017) methodological perspective, this approach emphasizes the in-depth analysis of individual cases to uncover nuanced aspects of language practices within diverse classroom settings. While case studies may not yield broad generalizations, they serve as invaluable tools for probing complex social phenomena. Therefore, by delving deeply into the experiences of these four STEM educators, the study aims to

reveal the dynamics of language usage and its implications for learners' conceptual understanding.

To ensure the relevance and appropriateness of participants, we utilized purposive sampling, aligning with specific criteria relevant to the research questions (Palinkas et al., 2015). The sample comprises eight STEM educators, with two specializing in each distinct STEM subject, and all actively teaching Grade 10 to 12 students in Johannesburg, South Africa. This intentional selection is designed to offer valuable insights into language practices within multilingual STEM classrooms.

Data collection involves two methods: lesson observations and semi-structured face-to-face interviews. Educators are observed during STEM instruction, allowing real-time data collection on language practices within authentic classroom settings. Semi-structured individual interviews, conducted during lunch breaks, provide deeper insights into their perspectives and experiences regarding language practices in multilingual STEM classrooms.

The collected data undergoes a descriptive analysis approach (Loeb et al., 2017). Transcriptions, organization, and analysis are conducted to identify common themes and unique facets related to participants' perspectives, experiences, and insights concerning language practices within multilingual STEM classrooms. The close-reading approach ensures a profound understanding of the data, unveiling themes and subtleties in participants' language, viewpoints, and experiences. Member checking enhances data accuracy and reliability, involving participants in reviewing audio recordings and transcripts to provide feedback or clarifications.

Ethical considerations are paramount. Ethical clearance from the University of South Africa's College of Education ensures adherence to ethical guidelines and protocols. This includes safeguarding participants' rights and privacy, securing informed consent, and ensuring confidentiality and anonymity. Rigorous data analysis and ethical considerations aim to offer credible and dependable insights into language practices within multilingual STEM classrooms, reflecting the researchers' commitment to conducting the study with integrity and respect for participants.

RESULTS AND DISCUSSION

This study aimed to comprehensively understand language practices in multilingual STEM classrooms and their impact on learners' conceptual learning. Through meticulous data collection and analysis involving observations and semi-structured interviews, we explored the intricate dynamics of language usage in South African STEM education. Our rigorous approach illuminated nuanced aspects of language practices, providing valuable insights to enhance educational practices in multilingual STEM classrooms.

To offer a representative sample of results, this study highlights select excerpts, emphasizing common themes derived from participants' perspectives. This approach contributes to a deeper understanding of language's role in diverse STEM classroom settings, addressing themes such as the dominance of English, language's impact on STEM education, teaching philosophies in multilingual STEM classrooms, and the significance of family engagement.

Theme 1: The Dominance of English in Multilingual STEM Classrooms

Our study's findings align with existing literature, emphasizing English as the primary language employed by the Grade 11 science educator in their interactions with learners and in administered tasks and tests. The educator explicitly stated that *this language choice is aimed at providing learners access to a broader spectrum of social and academic opportunities, underscoring English's global status as a language of science and communication*. However, despite these advantages, challenges emerge from the widespread use of English. Moreover, the Grade 12 science educator acknowledged that *English presents challenges, especially for learners who are not fluent in the language or have a different home language, particularly in understanding scientific concepts*. As a result, language comprehension becomes a significant barrier, affecting some learners' capacity to fully comprehend complex scientific ideas when taught exclusively in English. This difficulty has the potential to impede their overall understanding and conceptual development in STEM subjects.

The study's findings underscore a critical aspect regarding the cognitive demands of tasks assigned to learners. Extensive lesson observations in the Grade 10 technology classroom revealed a significant revelation. Specifically, certain written tasks were identified as misaligned with the learners' grade level. Moreover, these tasks primarily relied on rote memorization, lacking opportunities to connect technology principles to real-world applications, particularly given the absence of computers for learners to practice the acquired skills. This instructional approach has the potential to hinder learner engagement and impede their capacity to critically apply scientific knowledge.

In response to this identified challenge, the Grade 11 engineering educator recommended reducing the complexity of written assignments, as they may hinder students' comprehension of higher-order questions due to English language proficiency. The educator stated that *it is of utmost importance to promote peer collaboration through activities such as project-based assignments, conducting experiments, fostering group discussions, and organizing field trips where learners can interact with each other in their native language*. These interactive and inquiry-based approaches are crucial for developing a profound conceptual understanding of the subject matter. Consequently, embracing a more interactive and inquiry-based learning environment encourages learners to cultivate critical thinking skills and effectively apply their scientific knowledge in meaningful and practical contexts. This approach not only enhances comprehension of scientific concepts but also enables learners to leverage their linguistic diversity as an asset in the learning process.

The alignment with previous research, particularly the indication that English serves as the primary language in interactions and assessments, supports the theoretical framework (Babaci-Wilhite, 2013; González-Howard & Suárez, 2021). The emphasis on choosing English as the medium of instruction for broader social and academic opportunities aligns with the theoretical underpinning that language plays a crucial role in shaping educational experiences (Murray & Christison, 2019).

Challenges arising from the prevalent use of English, as highlighted by the mathematics educator, add depth to the theoretical understanding (Mlay, 2010). This acknowledgment of difficulties for learners not fluent in English aligns with the theoretical perspective that language comprehension is a significant factor influencing overall understanding and conceptual development in STEM subjects (National Academies of Sciences, Engineering, and Medicine, 2018).

The insights into the cognitive demands of tasks, especially the misalignment and reliance on rote memorization in the technology classroom, contribute to the theoretical understanding of effective instructional approaches (Biggs, 2014). The recommended strategies by the engineering educator, such as reducing complexity and promoting peer collaboration in native languages, align with the theoretical emphasis on interactive and inquiry-based learning environments for profound conceptual understanding (Chu et al., 2021).

Building upon these findings, the study aligns with prior research, reinforcing the theoretical proposition that incorporating learning materials in multiple languages can be a valuable strategy for accommodating diverse language backgrounds (Babaci-Wilhite, 2013; González-Howard & Suárez, 2021). The integration of the Whole Language Approach and family involvement as language support providers aligns with the theoretical foundation, emphasizing the importance of addressing language barriers in multilingual STEM classrooms to optimize educational practices (Hooper, 1994). In essence, the study's findings provide empirical support for the theoretical framework, offering a nuanced understanding of language practices in multilingual STEM classrooms and their implications for learners' conceptual learning.

Theme 2: The Dynamic Impact of Language on STEM Education in Multilingual Classrooms

This theme reveals the pivotal role of language as a medium of instruction in secondary education, significantly impacting learners' experiences, cognitive development, and overall academic achievements, especially in STEM subjects. The Grade 10 mathematics educator's closely observed lessons provide profound insights into how language choices influence the learning experiences and academic success of adept STEM learners, with a specific focus on the intricate domain of mathematics.

The mathematic educator's seamless interchange between English and the learners' indigenous language highlights an adaptive instructional approach. Purposefully bridging the language gap, this method establishes a supportive learning environment that accommodates the linguistic diversity of the students (Faltis & Valdés, 2016). The science educator's recognition of challenges faced by some learners in comprehending complex scientific concepts solely in English underscores the need for a nuanced approach (National Research Council, 2001). Therefore, by integrating the learners' indigenous language, the educators aim to enhance understanding, stimulate active engagement, and foster effective problem-solving skills.

Our findings align seamlessly with the study's objective, emphasizing the crucial need to recognize and accommodate linguistic diversity within the classroom

(Uy et al., 2023). This aligns with the theoretical framework that posits language as a significant factor influencing academic experiences in STEM education (Tang et al., 2023). The observed higher engagement and confidence exhibited by learners when taught in a familiar language confirm the profound impact of language choice on their academic journey in STEM subjects.

The theoretical foundation, as proposed by Mlay (2010), underscores the pivotal role of educators in fostering positive educational journeys by acknowledging and leveraging the influence of language. The importance of adopting inclusive approaches in STEM education is evident in our findings, highlighting the imperative for educators to empower learners, enabling them to excel not only in mathematics or science but also in other STEM subjects. This aligns with the overarching goal of ensuring equitable access to quality education and facilitating learners in reaching their full potential in STEM fields and beyond.

Our study contributes to the understanding of the dual nature of language in the classroom, drawing parallels to the theoretical argument presented by Lave and Wenger (1991). Language, like technology in STEM learning, should be visible enough for comprehension but invisible enough not to distract during interactions (Setati, 2010). This complex interplay of visibility and invisibility, identified in our study, adds depth to the theoretical framework, emphasizing the intricate dynamics of language in the context of STEM education (Blommaert et al., 2005).

In this regard, our study's findings underscore the critical role of language in shaping learners' academic experiences and achievements within the STEM domain (Steenbergen-Hu & Olszewski-Kubilius, 2017). The observed positive outcomes, such as increased engagement and confidence when learners are instructed in a familiar language, highlight the practical implications of embracing inclusive instructional approaches (Moriarty, 2007). Educators, through their acknowledgment of language's dual nature, are empowered to create supportive environments that foster excellence in STEM education (Howard et al., 2007).

The study's insights align with and contribute to the theoretical framework by emphasizing the significance of language in shaping educational experiences (Wells, 1999). Educators, by recognizing and utilizing the dual nature of language, can optimize instructional effectiveness. This aligns with the theoretical proposition that a thoughtful and inclusive approach to language in STEM classrooms contributes to learners' successful attainment of their full potential in STEM fields (Lynch et al., 2018). The findings emphasize the practical application of the theoretical concepts, providing actionable insights for educators aiming to enhance STEM education through language inclusivity (O'Leary et al., 2020).

Theme 3: Teaching Philosophies in STEM Multilingual Classrooms

This theme delves into the divergent teaching philosophies demonstrated by Grade 12 technology and engineering educators. One educator adopts a realist perspective, prioritizing precision and accuracy in conveying information about computer systems, programming languages, and software applications. In contrast,

the other embraces a constructivist approach, recognizing that learners actively construct knowledge through engagement and hands-on experiences.

The technology educator underscores the importance of transmitting established and factual information, emphasizing precision in comprehending computer systems, programming languages, and software applications. The educator stated that the goal *is to equip learners with a solid foundation and technical expertise, preparing them for the rapidly evolving field of technology*. While recognizing the value of prior knowledge, the objective is to provide learners with an objective understanding, thereby readying them for real-world applications and challenges in the digital realm.

In contrast, the Grade 12 engineering educator's constructivist approach places value on the active construction of knowledge by learners. The educator explicitly stated that they *encourage learners to share ideas and perspectives, fostering a collaborative learning environment for a deeper understanding of technical drawing concepts*. Additionally, the educator actively embraces linguistic and cultural diversity, encouraging learners to express design ideas in their native languages, thereby promoting inclusion and appreciation for diverse perspectives. The ultimate goal, as articulated by the educator, is to nurture creativity, foster problem-solving skills, and cultivate critical thinking, ultimately empowering learners to become independent and skilled technical drawers.

The study's findings shed light on the divergent teaching philosophies in Grade 12 technology and engineering, revealing the integration of realist and constructivist approaches in STEM education. This coherence with existing literature emphasizes the importance of blending these methodologies to cater to diverse learning needs in multilingual classrooms (Herzog-Punzenberger et al., 2017) The technology educator's emphasis on the realist approach aligns with Yang et al.'s (2020) research, highlighting the value of a robust knowledge base in STEM, particularly in technology-related fields. This study validates the realist approach's focus on constructing a strong foundation, enabling students to comprehend intricate concepts and apply their skills effectively in practical scenarios. In contrast, the engineering educator's embrace of the constructivist approach aligns with Jones et al.'s (2019) work, underscoring the significance of recognizing linguistic and cultural diversity. The study affirms that the constructivist approach, involving hands-on experiences and collaborative interactions, fosters creativity, critical thinking, and problem-solving skills among learners (Chen, 2021).

The study's proposition that educators can benefit from adopting either the realist or constructivist approach, depending on the subject and learning objectives, receives support from Bray & Tangney's (2016) comprehensive study. This study delves into the combined impact of realist and constructivist approaches on academic achievement and engagement in STEM subjects, indicating improved learning outcomes and heightened motivation. Moreover, the meta-analysis conducted by Lee et al. (2018) substantiates these findings, confirming that the integration of realist and constructivist teaching methods fosters a deeper conceptual understanding and enhances critical thinking skills in learners within STEM classrooms.

Ultimately, the study advocates for the adoption of either a realist or constructivist approach in teaching STEM subjects in multilingual classrooms, emphasizing the importance of linguistic and cultural diversity for positive educational outcomes (National Academies of Sciences, Engineering, and Medicine, 2018). Acknowledging the value of both orientations and tailoring instructional strategies accordingly is crucial for creating a dynamic and inclusive learning environment. The incorporation of insights from Lee et al. (2018) equips educators to prepare students for future STEM careers, contributing to the development of a new generation of skilled and motivated STEM professionals in our interconnected world. The integration of realist and constructivist approaches in multilingual STEM classrooms underscores the adaptability and innovation required to meet the challenges of a diverse and interconnected global society (Song et al., 2023).

Theme 4: The Significance of Family Engagement in Multilingual STEM Classrooms

This theme underscores the pivotal role of family engagement in promoting active learning within multilingual STEM classrooms, as evident from the comprehensive findings and discussion presented. Recognizing the crucial role families play in the educational journey, especially in multilingual contexts, emphasizes their imperative involvement in enhancing learners' experiences and academic achievements in STEM disciplines. The theme gains prominence through the substantiation of the emphasis on fostering collaboration between families and schools and the proposition of a tailored STEM-Based Engagement Activity for multilingual families. Furthermore, it acknowledges how family engagement positively influences learners' scientific proficiency and language development, signifying the multifaceted benefits of incorporating families as vital partners in the educational process.

In the context of Grade 11 mathematics, the educator emphasized *that family engagement through collaborative efforts can lead to improved engagement and academic outcomes*. Parents, as collaborators, play a crucial role in reinforcing STEM concepts at home, providing practical examples, and encouraging exploration of STEM-related activities beyond the classroom. Such collaborations foster a sense of belonging and motivation, enhancing learners' interest and success in the subject. In mathematics, where language comprehension is critical, the educator pointed out that *family involvement becomes even more vital*. Actively participating in their children's mathematical education enables families to help overcome language barriers and promote a deeper understanding of mathematical concepts. Parents can engage in problem-solving activities, support mathematical practice at home, and celebrate their children's achievements, contributing to improved confidence and performance in Mathematics.

The study's findings highlight the crucial role of family engagement in supporting learners within multilingual STEM classrooms. Active family participation in their children's education establishes a robust support system, positively influencing the learning process (Desforges et al., 2003). This aligns

seamlessly with previous research that underscores the pivotal role of family involvement in promoting academic achievement and cultivating positive attitudes toward school (Fan & Chen, 2001). In multilingual settings, where learners may face language and cultural challenges, family engagement becomes even more critical, providing essential assistance and encouragement to overcome these barriers (Good et al., 20. This observation concurs with prior research emphasizing the positive impact of family support on the academic success of multilingual learners (Chang & Romero, 2008).

The study strongly advocates for the implementation of a STEM-Based Engagement Activity with Multilingual Families, drawing inspiration from Hoffman et al.'s (2021) integrated approach to STEM. This recommendation aligns with existing literature, emphasizing the necessity for innovative and inclusive strategies to engage families from diverse linguistic backgrounds in STEM education (Colegrove & Krause, 2017). The findings shed light on the World-Class Instructional Design and Assessment's identification of four crucial family engagement components: Awareness, advocacy, trust-building, and learning-connecting (WIDA Consortium, 2009). These components emphasize the importance of educators recognizing the potential rift between families and schools and being open-minded to restore families' epistemic content knowledge (Garcia et al., 2016). Moreover, the findings underscore the essential role of strong connections between families and schools in implementing teaching practices that are sensitive to linguistic diversity and rich in context. This recommendation aligns with the literature promoting culturally responsive teaching practices to address the needs of diverse learners (Gay, 2010).

To alleviate the stress associated with STEM education for multilingual learners, the findings suggest emphasizing the significance of taking risks rather than solely focusing on providing correct answers (Tanveer, 2007). This approach resonates with research advocating for creating a supportive and risk-free learning environment to foster learners' confidence and exploration (Clapper, 2010). Consequently, the findings of this study underscore the critical role of family engagement in supporting learners in multilingual STEM classrooms. The proposed adoption of a STEM-Based Engagement Activity with Multilingual Families, coupled with the incorporation of the World-Class Instructional Design and Assessment's family engagement components, can enhance the educational experiences and outcomes of multilingual learners in STEM education. These insights contribute significantly to the existing literature on the importance of family involvement and culturally responsive teaching practices in supporting diverse learners in STEM subjects.

CONCLUSION

In conclusion, this study delves into the complex language dynamics of multilingual STEM classrooms, offering valuable insights for enhancing educational practices. The implications underscore the challenges posed by English dominance, urging educators to adopt inclusive strategies such as peer collaboration. Recognizing language's dynamic impact, adaptive instructional approaches should seamlessly incorporate learners' languages, fostering understanding and problem-solving skills.

Teaching philosophies vary, with a blend of realist and constructivist approaches proving effective. Educators should tailor strategies to subject requirements, creating an inclusive environment for creativity and critical thinking. Family engagement is pivotal, forming a robust support system through collaborative efforts and STEM-Based Engagement Activities. Recommendations include embracing language-inclusive strategies, adaptive instruction, a blend of teaching philosophies, and innovative family engagement approaches. These insights guide stakeholders in optimizing multilingual STEM classrooms for the development of skilled and motivated professionals in our interconnected global society.

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