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Translanguaging and code-switching in Southern African Science and Mathematics Education: Mapping pedagogical practices and teacher development implications

Bongani Prince Ndlovu[1] Hlologelo Climant Khoza[2] & Sebastian Sanjigadu [3]

[1] University of KwaZulu-Natal, South Africa.
[2] University of Pretoria, South Africa.
[3] Central University of Technology, South Africa.

ABSTRACT

In the linguistically diverse Southern African Development Community (SADC) region, English, along with colonial languages, serves as the primary medium of instruction in science and mathematics. This creates significant barriers for students with limited language proficiency who struggle to master complex scientific and mathematical concepts. This conceptual paper presents a qualitative meta-synthesis of twelve studies investigating translanguaging and code-switching as pedagogical strategies in science and mathematics classrooms in multilingual SADC contexts. Four key themes emerge from the analysis: codeswitching practices in multilingual teaching contexts, codeswitching as a learning empowerment strategy, teachers' beliefs about native language instruction, and students' perceptions of multilingual learning experiences. The findings demonstrate that while translanguaging and code-switching offer substantial pedagogical benefits, their effectiveness depends on consistent implementation grounded in sound educational theory. Teachers require robust pedagogical content knowledge (PCK) that encompasses both disciplinary understanding and multilingual competencies to navigate the documented tensions between concerns about English language development and diverse student perspectives on the use of native language. The study argues that effective multilingual pedagogy requires systematic implementation, culturally responsive approaches, and comprehensive teacher development frameworks. These findings have critical implications for educational practice, advocating for the integration of translingual competencies in teacher education programs to cultivate culturally responsive pedagogies that advance educational equity. The paper concludes that initial teacher education and professional development must systematically integrate multilingual pedagogical competencies through structured training, lesson study approaches, and collaborative teacher-led professional learning communities.

Keywords: Translanguaging, Codeswitching, PCK, Native language, Second Language Acquisition

INTRODUCTION

The intersection of language and disciplinary learning represents one of the most complex challenges facing contemporary education systems, particularly in postcolonial contexts where colonial languages

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CORRESPONDENCE – Sebastian Sanjigadu Email: ssanjigadu@cut.ac.za
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continue to dominate formal instruction.[1] This challenge is acutely pronounced in science and mathematics education, where the acquisition of disciplinary knowledge is inextricably linked to the mastery of specialized linguistic codes and terminologies.[2] Understanding how multilingual pedagogical approaches can bridge the gap between students' linguistic repertoires and disciplinary demands become increasingly important for educational equity and subject epistemic quality.

The Southern African Development Community (SADC) region exemplifies a linguistic complexity, characterized by diverse cultural and ethnic groupings with unique languages that serve as primary vehicles for social interaction and cognitive development.[3] However, the colonial grip and legacy have entrenched English as the dominant language of teaching and learning in science and mathematics education, creating a fundamental pedagogical paradox where students must simultaneously acquire disciplinary content knowledge while navigating the linguistic demands of a non-native language.[4]

This dual burden is particularly problematic in science and mathematics, disciplines characterized by precise, objective language registers that incorporate both technical terminology (discipline-specific concepts with no everyday equivalents) and non-technical threshold concepts that carry specialized meanings distinct from their everyday usage.[5] The consequences of this linguistic mismatch are empirically documented. In South Africa, underperformance in science and mathematics subjects reflects broader systemic challenges. Fewer than 50% of matriculants achieve 40% or less in Science, and similar trends in mathematics have been reported for the past six years. These outcomes reflect the complex interplay between Second Language Acquisition (SLA) processes and disciplinary concept acquisition.[6]

In response to these challenges, science and mathematics teachers across these multilingual contexts have increasingly adopted translanguaging and code-switching as pedagogical strategies. Code-switching, defined as the strategic alternation between two or more languages or language varieties within communicative contexts,[7] represents a communicative phenomenon where bilingual speakers navigate multiple linguistic repertoires based on contextual demands.[8] However, translanguaging extends this concept by recognizing the fluid boundaries between languages, allowing individuals to draw from diverse linguistic resources, including native languages, colonial languages, and disciplinary registers, to construct meaning and facilitate learning.[9]

Recent review studies have examined the use of native languages in mathematics, as well as in mathematics and science teaching.[10] However, existing literature reviews have provided limited systematic examination of how multilingual pedagogical approaches function across SADC contexts, where linguistic diversity intersects with postcolonial educational structures, and the implications for teacher preparation remain underexplored. Although these reviews have established the general efficacy of translanguaging in South African contexts and map the broader research landscape, a critical need

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1 Carolyn McKinney, *Language and Power in Post-Colonial Schooling: Ideologies in Practice* (Routledge, 2016).

2 H. C. Khoza, "Leveraging Teacher Educators' Pedagogical Approaches for Biology Terminology Instruction: A South African Case Study," *International Journal of Social Sciences & Educational Studies* 12, no. 1 (2024), https://doi.org/10.23918/ijsses.v12i1p1; Jay L Lemke, *Talking Science: Language, Learning, and Values.* (ERIC, 1990).

3 Neil Mercer, *Words and Minds* (Routledge, 2002), https://doi.org/10.4324/9780203464984.

4 Bill Clark, *Students in Transition: Introducing English Language Learners from Asia, Africa, and the Middle East to US History* (The University of Vermont and State Agricultural College, 2018).

5 Henri Béjoint, "Scientific and Technical Words in General Dictionaries," *International Journal of Lexicography* 1, no. 4 (1988): 354–68, https://doi.org/10.1093/ijl/1.4.354; Stephen Pickersgill and Roger Lock, "Student Understanding of Selected Non-Technical Words in Science," *Research in Science & Technological Education* 9, no. 1 (January 1991): 71–79, https://doi.org/10.1080/0263514910090107.

6 Rod Ellis, "SLA and Language Pedagogy: An Educational Perspective.," *Studies in Second Language Acquisition* 19, no. 1 (March 1, 1997): 69–92, https://doi.org/10.1017/S0272263197001058.

7 Carol Myers-Scotton, "Comparing Codeswitching and Borrowing," *Journal of Multilingual and Multicultural Development* 13, no. 1–2 (January 14, 1992): 19–39, https://doi.org/10.1080/01434632.1992.9994481.

8 Olagunju Robert Modupeola, "Code-Switching as a Teaching Strategy: Implication for English Language Teaching and Learning in a Multilingual Society," *IOSR Journal of Humanities and Social Science* 14, no. 3 (2013): 92–94.

9 David Chen-On Then and Su-Hie Ting, "Code-Switching in English and Science Classrooms: More than Translation," *International Journal of Multilingualism* 8, no. 4 (November 2011): 299–323, https://doi.org/10.1080/14790718.2011.577777.

10 Erasmos Charamba, "Translanguaging as Bona Fide Practice in a Multilingual South African Science Classroom," *International Review of Education* 69, no. 1–2 (April 13, 2023): 31–50, https://doi.org/10.1007/s11159-023-09990-0.;Anthony A Essien and Matshidiso Moleko, "Research on Language and Multilingualism in Mathematics Education in Sub-Saharan Africa," *Africa Education Review* 21, no. 1 (January 2, 2025): 25–49, https://doi.org/10.1080/18146627.2025.2455577.

remains for a focused exploration of pedagogical approaches that systematically integrate translanguaging and code-switching strategies to teach complex concepts of science and mathematics across the diverse multilingual contexts of Southern Africa.

Hence, this conceptual paper addresses these issues through a qualitative meta-synthesis of empirical research examining translanguaging and code-switching in multilingual science and mathematics classrooms, with particular emphasis on SADC countries. This synthesis contributes to global understanding of multilingual pedagogy while honouring the specific linguistic and cultural dynamics that shape educational experiences across the African continent. The study is guided by the following two primary research questions.

1. What can be gleaned from the existing studies about the use of translanguaging and code-switching as pedagogical approaches in teaching science and mathematics concepts?
2. What implications do translanguaging and code-switching pose for initial teacher development and professional practice in science and mathematics education?

In response to the first conceptual question, a scoping review of the literature was conducted to gain insight from previous studies in SADC countries on how teachers use the native languages of students to inform their classroom practice. The SADC region includes 16 countries in the Southern and Eastern part of Africa, which are populated by people who speak more than 100 different indigenous languages.[11] The resulting conceptual synthesis of this review informed the views of researchers on the roles that translanguaging and code-switching play in science and mathematics instruction. In response to the second question, this was unpacked as implications for teachers' professional practice and initial teacher education, primarily focusing on the role that both translanguaging and code-switching play in reiteration and how that role relates to translation and the teaching of the threshold concepts in science and mathematics.

THEORETICAL FRAMEWORK

To explore the role of translanguaging and codeswitching in multilingual classrooms where English is the language of instruction for science and mathematics subjects, this paper draws from the SLA theory. Stephen Krashen developed the SLA theory in the 1980s to explain how individuals who have acquired one language can learn a new language in a different context.[12] The acquired language in this study refers to the native languages that students use in their everyday lives and bring to the classroom to learn new science and mathematics language. Krashen argued that language acquisition occurs through studying the rules and patterns of a language. SLA theory describes science teaching and learning as language acquisition. SLA in science and mathematics refers to the process by which students learn scientific and mathematical concepts and terminologies in a language that is not their first language.[13] Therefore, it involves not only learning the content knowledge but also developing the necessary language skills to understand and communicate that knowledge. Figure 1 is a visual depiction of the organic process of the SLA as propagated by Krashen.[14]

[11] Michael M Kretzer and Russell H Kaschula, *Handbook of Language Policy and Education in Countries of the Southern African Development Community (SADC)*, vol. 3 (Brill, 2022).
[12] Stephen Krashen, "Second Language Acquisition," *Second Language Learning* 3, no. 7 (1981): 19–39.
[13] J. Norris and L. Ortega, "Defining and Measuring SLA," in *The Handbook of Second Language Acquisition*, ed. Catherine J. Doughty and Michael H. Long (Wiley, 2003), https://doi.org/10.1002/9780470756492.
[14] Krashen, "Second Language Acquisition."

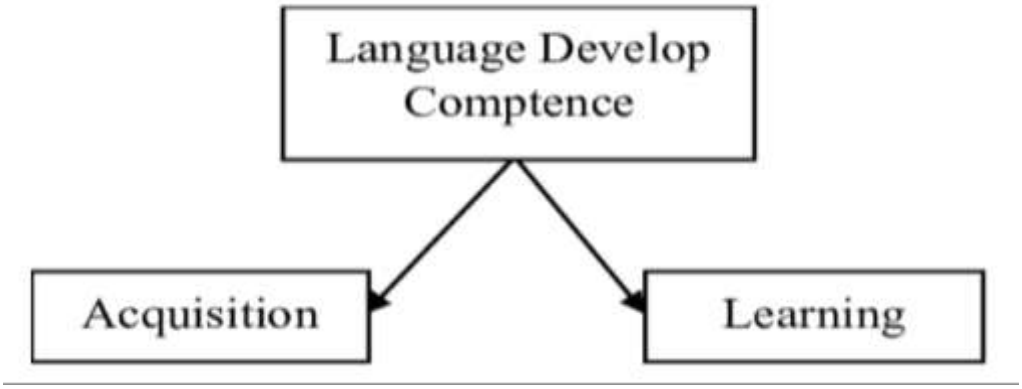

Figure 1. Language Development Competence by Krashen (Krashen, 1981)[15]

Language is used as the trigger to activate what the students have acquired. There is a fundamental difference between acquiring a language (in this case, the LoLT) and learning a language. Littlewood observes that second language acquisition involves more than just learning vocabulary and grammar structures.[16] Students may acquire the mechanics of a language without developing the cognitive ability to think fluently in that language, which can potentially limit their capacity for effective learning through the medium of their second language. This understanding is significant in that students learning science and/or mathematics, regardless of their proficiency in speaking English, may not be able to process information or learn effectively in English. i.e., the acquisition of a language may not be an indicator of competence in a specific subject or topic. The discussion of SLA in the SADC region is pertinent.

In addition to the SLA theory, this study also draws from the socio-cultural theory (SCT) by Vygotsky. It draws from one of the SCT tenets that language is an essential tool for learning and thinking.[17] Accordingly, SCT views language as a vital tool for shaping understanding of the world and the process of internalizing new knowledge. This directly applies to the SLA theory. As students use their native language to navigate concepts of science and mathematics.[18] It becomes a crucial mediator for understanding the latest concepts and social situations embedded within the discipline. Engaging in a new language goes beyond fluency. It fosters deeper understanding by internalizing new knowledge and developing critical thinking skills.[19] This happens when learners actively participate in meaning-making, analyze language structures, and reflect on their learning journey. This article acknowledges that focusing on language and learning science and mathematics from the perspective of the SLA theory creates an unjust barrier for non-native speakers, thus limiting their potential in these subjects.

METHODOLOGY

This qualitative study employed a desktop design, which involved a systematic review. Tong et al. state that "systematic reviews of multiple empirical qualitative studies bring together findings from different studies to offer new and more comprehensive understandings of social phenomena across various contexts."[20] This review followed a qualitative meta-synthesis of studies that explored how science and mathematics teachers leverage students' native languages for practical instruction in multilingual classrooms. It drew on some of the studies conducted in the Southern African region between 2014 and 2024. The aim was to synthesize insights from existing studies and develop a conceptual argument about

[15] Krashen, "Second Language Acquisition."
[16] William Littlewood, "Second Language Learning," *The Handbook of Applied Linguistics*, 2004, 501–24.
[17] James P. Lantolf and Aneta Pavlenko, "Sociocultural Theory and Second Language Acquisition," *Annual Review of Applied Linguistics* 15 (March 19, 1995): 108–24, https://doi.org/10.1017/S0267190500002646.
[18] Nkonko M Kamwangamalu, *Language Policy and Economics: The Language Question in Africa* (Springer, 2016).
[19] Aleidine Kramer Moeller and Theresa Catalano, "Foreign Language Teaching and Learning," 2015.
[20] Allison Tong et al., "A Guide to Reading and Using Systematic Reviews of Qualitative Research," *Nephrology Dialysis Transplantation* 31, no. 6 (2016): 897–903.

the use of translanguaging and code-switching as pedagogical approaches in teaching science and mathematics concepts. It focused on peer-reviewed studies that were conducted in English and published in credible journals. Content and thematic analyses guided this study.

The contents of various research papers focusing on 'Translanguaging and Code Switching within the SADC Countries' were reviewed, and recurrent themes were identified. The qualitative meta-analysis process drew on Naeem et al.'s process of thematic analysis. Once the relevant literature was reviewed and information related to the study's focus was identified, familiarization, initial coding, and theme identification occurred.[21] This was then followed by a review of the themes, including redefining and naming themes, as well as the reporting of the theme process.[22]

The focus was limited to studies in science domains, specifically the Natural Sciences, Physical Sciences, and Life Sciences. Additionally, studies in mathematics were also included in the review. All studies in other STEM fields, such as Technology and Engineering, were excluded. Furthermore, studies conducted outside of the SADC region were excluded. This formed the basis for the inclusion and exclusion criteria. Two of the three authors used EBSCOhost to access peer-reviewed articles using the following search words: 'Codeswitch-ing', 'Translanguaging', 'Teacher professional development', 'teacher education', and 'STEM Education'. Various combinations of these words were used to access articles within the specified time range. Table 1 below summarizes the reviewed studies, highlighting the focus of each study, its theoretical or conceptual framework, research design, emergent findings, and some of the implications that each study proposes.

Various limitations were identified in this study. The methodological choice of reviewing literature from 2014 to 2024 may have restricted the range of data collected, which was partially mitigated by also reviewing literature review papers and scoping reviews in an approach that encompassed a wider range of information beyond the scope of the study. A further limitation was the review of papers written and published in English. The SADC region is a diverse region with multiple languages that stem from a plurality of cultures, races, and people. The decision to review only English literature may have limited the scope of the study. To mitigate this, authors read widely, including using translation options on papers written in languages unfamiliar to them. However, this was not possible for all the literature reviewed, as many papers did not have this option.

[21] Muhammad Naeem et al., "A Step-by-Step Process of Thematic Analysis to Develop a Conceptual Model in Qualitative Research," *International Journal of Qualitative Methods* 22 (October 8, 2023), https://doi.org/10.1177/16094069231205789.
[22] Naeem et al., "A Step-by-Step Process of Thematic Analysis to Develop a Conceptual Model in Qualitative Research."

Table 1: **Summary of the Studies in Translanguaging and Code Switching within the SADC Countries**

Authors	Focus	Theoretical Framework	Findings	Implications
Siphelele Mbatha (2024)	Role of Translanguaging in Teaching Mathematics at an Adult learning Centre in South Africa	Fixed Language Approach-Fluid Languaging Approach	Translanguaging can be a resource for developing isiZulu-English vocabulary and mathematics register. Translanguaging as a strategy for decolonizing the mathematics curriculum in the correctional center classroom. Conceptualization of translanguaging as a catalyst for mathematics procedural fluency improvement in adult correctional center classrooms.	Policy development Adult Education Decolonization of the curriculum using translanguaging.
Motloung et al. (2021	Teachers' beliefs and practices when teaching in their second language (South Africa, life sciences)	Socio-constructivist perspective	Mixed views on the South African language policy that disadvantages township ESL speakers Teachers perceive strategies as most effective to counteract language difficulties in the subject and to elicit the participation of the learners. The use of English as a second language is perceived as a barrier to engagement in teaching and learning in the life sciences.	Policy monitoring Inclusive education
Kamati et al. (2022	Prevalence of code-switching in junior secondary education (Namibia, Physical Science)	Constructivism	The prevalence of code-switching in physical science classrooms was informed by the following: Class sizes, Learners' vs teachers' mother tongue, Teachers' and learners' verbal interactions, Teachers' code-switching	Policy and guidelines on code-switching. Bilingualism in formal assessment
Malulekе et al. (2020)	Impact of using code alternation in teaching science to English First Additional Language learners (South Africa, life sciences)	Not indicated	Classroom Observations: Approaches to Bridge the Language Gap Codeswitching Code mixing Interpretation of sentences	Psychosocial support for learners with less exposure to English
Malulekе (2019)	The use of code-switching as an empowerment strategy in teaching mathematics to learners with limited	Socio-constructivist perspective	Code-switching provides better learning outcomes than instruction in English only. Learners lack sufficient knowledge of English, which is the language of learning and teaching. The language of mathematics is very challenging, and learners find it difficult to understand. Code-switching serves as a mediation tool	A need for clear guidelines for the use of code-switching in teaching and learning.

	English proficiency in South African schools.	Socio-linguistic perspective	that bolsters class participation. Code-switching helps teachers to bond with learners and inspire them to love mathematics. Code-switching helps teachers evaluate whether learners understand the content taught.	
Chikiwa and Schafer	Teacher code-switching consistency and precision in a multilingual class (South Africa, Mathematics)	Dowling (1998) Framework: *esoteric, public, descriptive & expressive*	Classroom observation – teachers used their native language to ask questions and explain concepts. Approaches: Borrowing code-switching strategies Transparent code-switching strategies	Pedagogical implications with respect to consistency and precision
Grobler 2018	Students' perceptions of code-switching (South Africa, Natural Sciences)	Not indicated	Students indicated: Strong preference for the use of only English as the medium of instruction; Natural Sciences are easier to understand if code-switching between English and their home language was indeed used, yet some noted the confusion that code-switching presents; The positive impact of code-switching on their academic achievement	Policy Pedagogical, and Research
Malulek e (2019)	Code-switching as an empowerment strategy in teaching learners with limited proficiency in English (South Africa, Mathematics)	Not Indicated	Classroom observation showed that: Codeswitching encouraged positive learner participation. Improved learner outcomes in the subject Interviews revealed teachers' perceptions of code-switching. Learners with insufficient knowledge of English, The challenging nature of mathematical language and difficulties in learner understanding. Code-switching fosters learner participation in class Code-switching inspires learners to love mathematics.	Classroom practice Policy
Msiman ga and Lelliott (2014)	Talking Science in Multilingual Contexts in (South Africa, Chemistry)	Socio-cultural theory & Argumentation	Learner engagement with the task Negotiation of understanding of both the scientific concepts and the procedures to follow. High level of critique or evaluation of each other's ideas	Pedagogical Research dichotomy
Charam ba (2020)	Translanguaging in a multilingual class: the relation between	Learning as action and the	Role of language in academic performance of eighth-grade Natural Sciences students: understanding and engagement.	Pedagogical

	students' languages and epistemological access in science (South Africa, Natural Sciences)	Translanguaging theory	Effect of Natural Sciences learning materials written in students' home language: Improved academic performance.	
Probyn (2019)	The nature of the science content and the classroom language practices that support it. learners' opportunity to learn science in multilingual classrooms	Socio-cultural perspective and bi-/multilingualism	The opportunity to learn science was significantly greater when the teacher employed heteroglossic multilingualism in their teaching. content coherence dialogic discourse bridging discourse	Classroom practice Pedagogical
Denuga et al., 2017	Functions of code-switching in primary schools by science teachers (Namibia, Natural and Health Sciences	Constructivism and Socio-cultural perspective	Frequency of codeswitching CS was the most frequent with concepts that have local language equivalents. Reasons contributing to codeswitching. Mostly to stress a point, Semantic Significance, Lack of Register… and least to attract attention.	Classroom practice policy

DISCUSSION

Research in the SADC has studied the role of native languages in teaching and learning science and mathematics subjects in primary and secondary schools, particularly in the context of multilingualism. Several studies have examined the prevalence and functions of code-switching in science and mathematics education, including Kamati et al. in junior secondary education and Denuga et al. in primary schools in Namibia.[23] In South Africa, scholars have investigated classroom practices that support learner opportunities to learn in multilingual environments.[24] Robertson and Graven looked at how students' native languages can be leveraged to teach mathematics.[25] Primarily, these studies used qualitative approaches, such as case studies and phenomenological methods, to examine language practices in science teaching.

Other studies have examined code-alteration in teaching science to English First Additional Language (FAL) speakers and code-switching as an empowerment strategy for learners with limited English language proficiency.[26]Although some qualitative approaches have been used, Malukeke used a mixed-method design to explore the possibilities and challenges of using the native languages of the learners in talking science in a multicultural context through argumentation.[27] Similarly, Charamba also used a mixed-method approach to investigate the relationship between student language and epistemological access to science.[28]

In addition to the above lines of research, another focus emerges from Motloung et al.[29] While they focused on practices for using native languages to teach science, they also explored teachers' beliefs about teaching with native languages. The other line of inquiry explored students' perceptions of code-switching in the natural sciences, using an exploratory mixed-methods approach.[30] Collectively, these studies contribute to a growing body of research on the complex interplay between language and science and mathematics education in diverse linguistic and cultural contexts. Many of the studies mentioned above have presented that the use of code-switching and translanguaging is an effective pedagogic tool for teaching and learning in science and mathematics classrooms.

From the theoretical positionings, most of the above-mentioned studies were underpinned by views associated with the social constructivist theory of learning. This theory purports to learn as a social enterprise in which knowledge is not an objective reality that exists independently of the knower. However, it is socially constructed through interactions with the environment and cultural processes.

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[23] Aina Mewiliko Kamati, Leena Lahja Tileni Nghipandulwa, and Moses Chirimbana, "A Study about the Prevalence of Code Switching in the Junior Secondary Physical Science in the Oshana Education Region," *Creative Education* 13, no. 11 (2022): 3624–41, https://doi.org/10.4236/ce.2022.1311231; Desalu Denuga, Abah James, and Enghono Michael, "An Investigation into the Prevalence of Code Switching in the Teaching of Natural Science and Health Education in Three Primary Schools at the Zambezi Region in Namibia," *International Journal of Research in Engineering and Science (IJRES)* 5, no. 7 (2017): 55–61..

[24] Clemence Chikiwa and Marc Schäfer, "Teacher Code Switching Consistency and Precision in a Multilingual Mathematics Classroom," *African Journal of Research in Mathematics, Science and Technology Education* 20, no. 3 (September 27, 2016): 244–55, https://doi.org/10.1080/18117295.2016.1228823; Amos Ntokozo Motloung, Lydia Mavuru, and Carmel McNaught, "Teachers' Beliefs and Practices When Teaching Life Sciences Using Their Second Language," *South African Journal of Education* 41, no. Supplement 1 (October 31, 2021): S1–15, https://doi.org/10.15700/saje.v41ns1a2005; Margie Probyn, "Pedagogical Translanguaging and the Construction of Science Knowledge in a Multilingual South African Classroom: Challenging Monoglossic/Post-Colonial Orthodoxies," *Classroom Discourse* 10, no. 3–4 (October 2, 2019): 216–36, https://doi.org/10.1080/19463014.2019.1628792.

[25] Sally-Ann Robertson and Mellony Graven, "Language as an Including or Excluding Factor in Mathematics Teaching and Learning," *Mathematics Education Research Journal* 32, no. 1 (March 10, 2020): 77–101, https://doi.org/10.1007/s13394-019-00302-0.

[26] Mzamani Johannes Maluleke, Ernest Kwesi Klu, and Vincent N. Demana, "The Impact of Using Code Alternation in Teaching Life Science to English First Additional Language Learners in South African Schools," *Academic Journal of Interdisciplinary Studies* 9, no. 6 (November 19, 2020): 175, https://doi.org/10.36941/ajis-2020-0122; Mzamani J Maluleke, "Using Code-Switching as an Empowerment Strategy in Teaching Mathematics to Learners with Limited Proficiency in English in South African Schools," *South African Journal of Education* 39, no. 3 (2019): 1–9.

[27] Maluleke, "Using Code-Switching as an Empowerment Strategy in Teaching Mathematics to Learners with Limited Proficiency in English in South African Schools."

[28] Erasmos Charamba, "Translanguaging in a Multilingual Class: A Study of the Relation between Students' Languages and Epistemological Access in Science," *International Journal of Science Education* 42, no. 11 (July 23, 2020): 1779–98, https://doi.org/10.1080/09500693.2020.1783019.

[29] Motloung, Mavuru, and McNaught, "Teachers' Beliefs and Practices When Teaching Life Sciences Using Their Second Language."

[30] Rina Grobler, "Students' Perceptions of Code-Switching in Natural Sciences Classrooms: A South African Perspective," *Africa Education Review* 15, no. 1 (January 2, 2018): 38–51, https://doi.org/10.1080/18146627.2016.1224593.

These studies collectively showed that the native language can enhance these social interactions in learning science and mathematics. built on the sociocultural theory's language tenet and the affordances of argumentation theory to investigate science talk in multilingual classrooms. On the other hand, used the translanguaging theory to examine the relationship between students' language and their epistemological access to science. Lastly, Dowling's framework on esoteric, public descriptive, and expressive domains was used to explore consistency and precision in codeswitching practices of teachers in a multilingual context.

Summarily, the review synthesis of the studies in Table 1 revealed four emergent themes that contribute to generating a conceptual argument, as gleaned from the literature by the authors in this paper. These are (i) *codeswitching practices in multilingual contexts when teaching science*, (ii) *codeswitching as a learning empowerment strategy in science and mathematics*, (iii) *teachers' beliefs about teaching science and mathematics in native languages*, and (iv) *students' perceptions about learning science and mathematics in their native language*. In the next section, the synthesis of literature from the four themes is presented.

Qualitative Meta-synthesis of Reviewed Studies

Codeswitching practices in a multilingual context when teaching science

The first theme of the conceptual argument looked at code-switching practices in a multilingual context when teaching science. highlighted several reasons that account for the prevalence of code-switching in teaching physical sciences to junior secondary learners in Namibia. These include class sizes, learners versus teachers' native languages, learners' and teachers' verbal interactions, and teachers' code-switching. Although noting these precursors that inform codeswitching practices, Denuga et al. reported earlier that natural and health science teachers used codeswitching for a variety of reasons.[31] The findings by Denuga et al. ranked these reasons as follows: (i) to stress a point, (ii) for semantic significance, (iii) lack of register, (iv) for learning and teaching support materials (v) as habitual behavior, (vi) to motivate other children, (vii) for realistic reasons, (viii) for understanding, (ix) to show identity in class, and (x) to attract students attention.[32] The frequency of codeswitching was notably high when their teachers were dealing with concepts that had a local language equivalent. According to Chikiwa and Schafer, this is a crucial pedagogical consideration that requires teachers to ensure consistency and precision when borrowing from a native language to explain disciplinary mathematical concepts. [33]

While observing the impact of code alteration in teaching science to English FAL learners, Maluleke et al. noted three approaches employed by teachers.[34] These include code-switching, code-mixing (combining elements from different languages within a single sentence), and sentence interpretation (using a native language to explain a sentence written in a non-native language). Their in-depth analysis of the written work of learners suggested a strong influence by their cultural background. The writing style of Maluleke et al. writing style reflects elements of traditional culture, oral storytelling techniques, and the rural environment in which they reside.[35] Additionally, their use of circumlocution, a tendency to express ideas with more words than necessary, aligns with a common characteristic of South African communication and contrasts with the typically concise style of formal English writing.[36] This form of communication requires classroom teachers to be well-versed in the traditions and cultural context of their students in order to communicate effectively. In African indigenous communities, especially, the oral traditions of storytelling, folktales, and poems were used as methods to teach younger generations

[31] Denuga, James, and Michael, "An Investigation into the Prevalence of Code Switching in the Teaching of Natural Science and Health Education in Three Primary Schools at the Zambezi Region in Namibia."
[32] Denuga, James, and Michael, "An Investigation into the Prevalence of Code Switching in the Teaching of Natural Science and Health Education in Three Primary Schools at the Zambezi Region in Namibia."
[33] Chikiwa and Schäfer, "Teacher Code Switching Consistency and Precision in a Multilingual Mathematics Classroom."
[34] Maluleke, Klu, and Demana, "The Impact of Using Code Alternation in Teaching Life Science to English First Additional Language Learners in South African Schools."
[35] Maluleke, Klu, and Demana, "The Impact of Using Code Alternation in Teaching Life Science to English First Additional Language Learners in South African Schools."
[36] Sarina Faryadi and Malek Panahi, "Investigating The Role of Circumlocution And Code-Switching Techniques In Improving Students' Speaking Skill," *Research in Teaching* 10, no. 2 (2022): 193–217.

about nature, life, and tradition. African children are more inclined towards the spoken word for learning and engagement, as opposed to written communication.

In terms of the use of the native language to teach in multilingual classes, two variations of codeswitching were noted. These are borrowing codeswitching strategies and transparent codeswitching strategies. indicated that teachers used these varying approaches to codeswitching to ask questions and explain concepts. However, these were often found to be inconsistent and lacking precision, which could potentially lead to confusion and miscommunication. Inconsistent code alteration can negatively impact students' understanding of disciplinary concepts and their ability to engage meaningfully in learning science. Just as asserted, translanguaging challenges monoglossic ideologies that privilege one language over others, promoting a more inclusive and equitable approach to learning science. In the SADC context, particularly in the South African context, teachers tend to code-switch using various indigenous languages, depending on the context.[37] For example, if a teacher is teaching a mathematics class in KwaZulu-Natal, many teachers tend to use IsiZulu, whereas a teacher teaching in the Eastern Cape would use IsiXhosa.

In summary, this theme highlighted various reasons for code-switching in science classrooms, including explaining complex concepts and supporting diverse learners to learn difficult concepts.[38] However, Chikiwa and Schafer emphasized the need for consistent and precise code-switching to avoid confusion.[39] Maluleke et al. observed the influence of cultural background on the writing of learners, highlighting the importance of cultural awareness of teachers.[40] Probyn advocates for translanguaging to break down language barriers and achieve inclusive science education.[41]

Codeswitching as a learning empowerment strategy in science

Secondly, the review also identified the second theme: codeswitching as a learning empowerment strategy in science. There is a consensus in the literature on the benefits of code-switching in teaching science. reported that it encouraged positive learner participation during lesson observations. This finding is similar to that of, who previously found that using students' home language increased learner engagement with the task. In addition to increased engagement with the task, also noticed that students used their home language to negotiate the understanding of scientific concepts and procedures while drawing in high-level critique of each other's ideas in science. In examining the relationship between students' native language and epistemological access in science, researchers agreed that understanding and engagement are enhanced by translanguaging practices when teaching Natural Sciences in the eighth grade. Both found that optimized students' engagement in the task and thus improved their academic success in the subjects.

From this theme, the potential of code-switching to empower students in science learning is extrapolated. Studies reveal that using students' home languages increases participation and engagement with scientific tasks. This deeper engagement fosters critical thinking and facilitates the negotiation of complex concepts among students. Additionally, research suggests that translanguaging, the strategic use of multiple languages, leads to enhanced understanding and academic success. These findings support the idea that code-switching can create a more inclusive and effective learning environment for science, ultimately benefiting students' educational outcomes.

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[37] Sibongile Shinga and Ansurie Pillay, "Why Do Teachers Code-Switch When Teaching English as a Second Language?," *South African Journal of Education* 41, no. Supplement 1 (October 31, 2021): S1–7, https://doi.org/10.15700/saje.v41ns1a1934.

[38] Denuga, James, and Michael, "An Investigation into the Prevalence of Code Switching in the Teaching of Natural Science and Health Education in Three Primary Schools at the Zambezi Region in Namibia"; Maluleke, Klu, and Demana, "The Impact of Using Code Alternation in Teaching Life Science to English First Additional Language Learners in South African Schools."

[39] Chikiwa and Schäfer, "Teacher Code Switching Consistency and Precision in a Multilingual Mathematics Classroom."

[40] Maluleke, Klu, and Demana, "The Impact of Using Code Alternation in Teaching Life Science to English First Additional Language Learners in South African Schools."

[41] Probyn, "Pedagogical Translanguaging and the Construction of Science Knowledge in a Multilingual South African Classroom: Challenging Monoglossic/Post-Colonial Orthodoxies."

Teachers' beliefs about teaching science and mathematics in native languages

The third theme focused on teachers' beliefs about teaching science and mathematics in native languages. Motloung et al. found that there are mixed views regarding the language policy that disadvantages township English Second Language (ESL) speakers.[42] Teachers face several challenges when teaching science in the language of the learners. These included the lack of subject-specific vocabulary, the difficulty of explaining complex concepts, and communication barriers with students.[43] While Maluleke focused on codeswitching as an empowerment strategy to teach learners with limited English language proficiency.[44] The author's study in 2019 also revealed some perceptions that teachers have regarding codeswitching. These included students' knowledge of English, the challenging nature of the discipline-specific language, how code-switching fosters student participation, and how it inspires a love for the subject. Based on the above synthesis, while most teachers in endorsed code-switching, valuing its ability to enhance student understanding and participation in the subject, some expressed concerns about its potential impact on English language development and performance in English-only assessments. Teachers identified various factors that influenced their use, including their own language proficiency, student preferences, and school policies. They emphasized the need for further professional development and resources to strengthen their code-switching skills and create a more inclusive learning environment for multilingual students.

Students' perceptions about learning science and mathematics in their native language

The last theme focused on students' perceptions of learning science and mathematics in their native language. Grobler revealed that students held different perceptions regarding learning Natural Science in their native language.[45] For example, they expressed a strong preference for learning in English as the medium of instruction. In contrast, the Natural Sciences students studied by Grobler showed that they find it easier to understand the subject if teachers code-switch between their native language and the language of instruction.[46] The reported perceptions were found to be similar to a study in mathematics and language conducted in another context.[47] In addition, these students highlighted the impact of codeswitching on their academic achievements, confirming other literature.[48]

Emerging views gleaned from the last theme revealed conflicting student perceptions about using their native language in Natural Science. Although some students preferred English-only instruction, others found code-switching between their native language and English helpful in understanding and even improving their academic performance. This diversity highlights the need to explore the factors influencing students' contrasting opinions to inform teaching practices that balance student preferences with the potential benefits of code-switching in science education.

Conceptual Argument

Drawing from the synthesis of the four themes, this study advances the following conceptual arguments from a pedagogical perspective. First, translanguaging and code-switching in science and mathematics classrooms represent more than mere linguistic accommodations; they constitute legitimate pedagogical strategies that require systematic implementation grounded in sound educational theory. The effectiveness of these practices is dependent on the ability of teachers to use them consistently and precisely,

[42] Motloung, Mavuru, and McNaught, "Teachers' Beliefs and Practices When Teaching Life Sciences Using Their Second Language."
[43] Motloung, Mavuru, and McNaught, "Teachers' Beliefs and Practices When Teaching Life Sciences Using Their Second Language."
[44] Maluleke, "Using Code-Switching as an Empowerment Strategy in Teaching Mathematics to Learners with Limited Proficiency in English in South African Schools."
[45] Grobler, "Students' Perceptions of Code-Switching in Natural Sciences Classrooms: A South African Perspective."
[46] Grobler, "Students' Perceptions of Code-Switching in Natural Sciences Classrooms: A South African Perspective."
[47] Aziz bin Nordin, "Students' Perception on Teaching and Learning Mathematics in English" (University Teknologi Malaysia. Skudai, 2003).
[48] Audrey Msimanga and Anthony Lelliott, "Talking Science in Multilingual Contexts in South Africa: Possibilities and Challenges for Engagement in Learners Home Languages in High School Classrooms," *International Journal of Science Education* 36, no. 7 (May 3, 2014): 1159–83, https://doi.org/10.1080/09500693.2013.851427; Maluleke, "Using Code-Switching as an Empowerment Strategy in Teaching Mathematics to Learners with Limited Proficiency in English in South African Schools"; Charamba, "Translanguaging in a Multilingual Class: A Study of the Relation between Students' Languages and Epistemological Access in Science."

transforming potential linguistic barriers into pedagogical bridges that facilitate conceptual understanding.[49] This pedagogical justification becomes essential for promoting student success, as it positions multilingual practices not as deficits to be overcome, but as resources to be strategically leveraged in science and mathematics instruction.

Second, the pedagogical integration of translanguaging and code-switching demands culturally responsive teaching approaches that acknowledge students' linguistic repertoires as valuable knowledge systems. Teachers who demonstrate cultural awareness and strategically employ multilingual practices create inclusive learning environments where diverse epistemological frameworks intersect with scientific discourse. This pedagogical stance transforms science and mathematics education from monolingual enterprises into multilingual spaces where students' cultural and linguistic identities become integral to their academic development.[50] Such inclusivity fosters a sense of belonging and empowers students to envision themselves as legitimate participants in scientific communities.

Third, documented tensions between teachers' concerns about English language development and students' conflicting perspectives on native language use reveal critical pedagogical challenges that require systematic attention.[51] Sanjigadu notes that educational access is inherently linked to language, which, in turn, is linked to culture, in a set of complex interactions.[52] These complexities underscore the need for comprehensive teacher professional development programs that encompass both the theoretical foundations and practical applications of multilingual pedagogies. Professional development initiatives must equip educators with the pedagogical tools to navigate multilingual science education effectively, ensuring that code-switching practices enhance rather than compromise students' academic trajectories. The pedagogical propositions of these arguments extend beyond classroom practice to encompass broader questions of educational equity, cultural sustainability, and the development of scientific literacy in multilingual contexts. A nuanced understanding of translanguaging and code-switching as pedagogical strategies can inform the development of inclusive educational practices that maximize student engagement while preserving the integrity of scientific discourse. Subsequently, the following implications are derived for the initial development of teachers and professional practice based on the conceptual argument.

Implications for Initial Teacher Development

Effective science and mathematics teachers require a strong foundation in Pedagogical Content Knowledge (PCK). This germane teacher knowledge encompasses not only content mastery but also the ability to understand and cater to students' prior knowledge.[53] These prior educational needs and knowledge include their language proficiency levels and cultural orientations. Acknowledging this pedagogical need, initial teacher education programs must equip pre-service teachers with the tools to navigate the complexities of linguistic and culturally diverse science and mathematics classrooms through systematic integration of multilingual pedagogical competencies.

One key area of focus should be the SLA theory alongside culturally responsive teaching frameworks. Understanding the dynamics of SLA allows teachers to better support students in acquiring the language skills crucial for academic success and effective communication in science and mathematics.[54] This theoretical foundation must be complemented by practical strategies, such as

[49] Chikiwa and Schäfer, "Teacher Code Switching Consistency and Precision in a Multilingual Mathematics Classroom."
[50] bin Nordin, "Students' Perception on Teaching and Learning Mathematics in English."
[51] Motloung, Mavuru, and McNaught, "Teachers' Beliefs and Practices When Teaching Life Sciences Using Their Second Language"; Grobler, "Students' Perceptions of Code-Switching in Natural Sciences Classrooms: A South African Perspective."
[52] Sebastian Sanjigadu, "The Road Less Travelled: Exploring the Planning and Preparation for a Critical Social Justice Module by the University of Kwa-Zulu Natal, South Africa," *E-Journal of Humanities, Arts and Social Sciences*, October 23, 2024, 61–81, https://doi.org/10.38159/ehass.20245125.
[53] Bongani Prince Ndlovu and Stephen Andrew Malcolm, "Changes in Pre-Service Teachers' Planned TSPCK in Stoichiometry After a TSPCK-Based Practicum," *African Journal of Research in Mathematics, Science and Technology Education* 26, no. 2 (May 4, 2022): 125–41, https://doi.org/10.1080/18117295.2022.2103291.
[54] Charamba, "Translanguaging in a Multilingual Class: A Study of the Relation between Students' Languages and Epistemological Access in Science"; Probyn, "Pedagogical Translanguaging and the Construction of Science Knowledge in a Multilingual South African Classroom: Challenging Monoglossic/Post-Colonial Orthodoxies."

translanguaging and code-switching, in which teachers strategically use both their native languages and the dominant language of instruction to create inclusive learning environments. This approach creates a scaffold for second-language learners that positions their linguistic repertoires as valuable pedagogical resources rather than barriers to overcome. Teacher educators must design their professional modules in PCK to develop teacher competence to use translanguaging and codeswitching consistently and precisely, ensuring that these practices enhance rather than compromising scientific discourse integrity.

Furthermore, the inherent difficulty of scientific and mathematical language necessitates alternative teaching strategies that place language at the pedagogical center. The synthesis revealed various multilingual teaching approaches, including borrowing and transparent code-switching strategies, code-mixing and interpretation of sentences.[55] Hence, teacher education degree programs need to include micro-teaching experiences in methodology modules, where pre-service teachers enact these variations and develop expertise to navigate the documented tensions between English language development concerns and diverse student perspectives on native language use.

Implications for Professional Practice

The conceptual argument above has important implications for the professional development of science and mathematics teachers. Research reveals that science and mathematics teachers rely heavily on disciplinary language in their classrooms, often differing significantly from the use of the language of their students. However, teachers tend to employ various language strategies only within their own classroom spaces, working in isolation. Therefore, innovative approaches to professional development are needed to address this concern. Therefore, it is argued that lesson study methods and the establishment of professional learning communities (PLCs) could offer valuable frameworks, as demonstrated by Ndlovu et al.[56] Lesson study approaches are particularly well-suited to multilingual contexts because they are context-driven and learner-focused.[57] These are all key elements of effective teaching in a linguistically diverse context.

Furthermore, addressing language issues in mathematics and science classrooms requires context-specific solutions. Traditional professional development approaches commonly follow a top-down model, with academics or lead teachers positioned as field experts. A more effective alternative should take a bottom-up approach, in which teachers themselves drive their professional learning. In this model, teachers collaborate to make deliberate decisions about translanguaging and codeswitching as instructional strategies to address language challenges in their specific classrooms.

This teacher-led professional development model can foster greater participation and build stronger communities of practice among teachers. Through creating spaces for sharing ideas within specific contexts, this approach focuses on a crucial goal. These included helping teachers better navigate the transition between everyday language and the specialized language of science and mathematics without compromising conceptual understanding.

CONCLUSION

This paper has argued that the integration of translanguaging and codeswitching in science and mathematics classroom instruction is a powerful social tool for enhancing learning. By leveraging students' native languages alongside the target language, teachers create a bridge to a deeper understanding of scientific concepts. This not only fosters a more engaging and supportive learning environment but also empowers all students, particularly multilingual learners, to thrive in science classrooms. Ultimately,

[55] Chikiwa and Schäfer, "Teacher Code Switching Consistency and Precision in a Multilingual Mathematics Classroom"; Maluleke, Klu, and Demana, "The Impact of Using Code Alternation in Teaching Life Science to English First Additional Language Learners in South African Schools."

[56] Bongani Prince Ndlovu, Sphesihle Winile Nsele, and Hlologelo Climant Khoza, "Enhancing Conceptual Teaching in Organic Chemistry through Lesson Study: A TSPCK-Based Approach," *Chemistry Teacher International* 7, no. 3 (September 25, 2025): 485–98, https://doi.org/10.1515/cti-2024-0124.

[57] Yumiko Ono and Johanna Ferreira, "A Case Study of Continuing Teacher Professional Development through Lesson Study in South Africa," *South African Journal of Education* 30, no. 1 (March 4, 2010): 59–74, https://doi.org/10.15700/saje.v30n1a320.

integrating the SLA theory explicitly into pre-service teacher education could potentially equip future educators with the skills they need to cater to the diverse needs of students in multilingual settings.

For practising teachers, the attributes of lesson study planning approaches following a bottom-up approach can be used to capacitate teachers with the necessary expertise to use their native language for teaching. This bottom-up approach gives teachers a voice in the communities to share their experiences democratically. Lesson studies can be a valuable forum for sharing best practices and fostering collaboration. As educators share their experiences and ideas on using their native languages for instruction, they can collectively strengthen science and mathematics education for all students.

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ABOUT AUTHORS

Bongani Prince Ndlovu (PhD) is a Lecturer in Science Education at the School of Education at the University of KwaZulu-Natal. His research includes preservice teacher professional development, particularly through topic-specific PCK and Teacher-related Science Content Knowledge (TerSCK).

Hlologelo Climant Khoza (PhD) is a Senior Lecturer in the Department of Science, Mathematics and Technology Education, Faculty of Education, University of Pretoria. His research interests include pre-service science teacher development and science classroom talk.

Sebastian Sanjiagdu (PhD; M. Ed [Cum Laude]; B. Ed Hons. B. Ed; PGDBA [Distinction]; MBA [Candidate]) is a Lecturer and Researcher at the Central University of Technology (CUT), Free State. Dr. Sanjigadu's field of interest is social justice education, with a scholarly focus on Education for Sustainable Development (ESD). Sebastian serves on the *Departmental Research and Innovation Committee* (DRIC) at CUT and, as of 2026 been appointed as a member of the *Editorial Board of Contemporary Education and Teaching Research (CETR), Hong Kong, Boni Future Digital Publishing*. Dr. Sanjigadu also serves as a co-editor of the *Journal of the British Academy (Special Issue) at Nottingham Trent University (United Kingdom)*.