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Science teaching in BRICS: A systematic review of pedagogical approaches and challenges

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Abstract

As major emerging economies, BRICS nations (Brazil, Russia, India, China, and South Africa) are prioritizing advancements in science education to drive innovation and sustainable development. This systematic review synthesizes insights across 55 studies on policies, practices, challenges, and innovations in science teaching and learning in BRICS countries. The analysis reveals shared goals of enhancing inquiry-based, technology-integrated, hands-on pedagogies and improving teacher competencies. However, systemic constraints like large classes, limited resources, assessment pressures and lack of local contextualization persist, exacerbated by cultural barriers in countries like South Africa. Variations also emerge in research foci, with Brazil emphasizing content knowledge, China evaluating interventions, India highlighting teacher-student roles and South Africa targeting systemic challenges. While common reform directions are evident, tailored interventions responding to each nation's unique developmental context are essential, given differing priorities. Developing context-specific solutions while collaborating to exchange best practices can enable BRICS countries to collectively strengthen science education. Cross-national comparisons reveal gaps in areas like cultural responsiveness, indigenous knowledge, and comparative outcome analyses that can be addressed in future research. As BRICS nations cooperate strategically amid shifting global paradigms, transforming science education by addressing systemic inequities and nurturing critical thinking is vital for developing talent and technological capabilities. Sustained improvements require reorienting assessment-driven structures towards creativity, curiosity and local relevance while considering cultural perspectives.

Keywords: science education, BRICS countries, educational policy, pedagogy, comparative education

INTRODUCTION

Science education is a crucial foundation for innovation, economic growth, and sustainable development in the modern knowledge economy (Heras & Ruiz-Mallén, 2017). The quality of science teaching in schools has a profound impact on shaping young minds and cultivating critical skills for STEM workforce (Tytler, 2020). This is particularly relevant for emerging economies seeking to build their scientific and technological capabilities amidst the forces of globalization and rapid societal transformations (Prinsloo, 2016). BRICS nations (Brazil, Russia, India, China, and South Africa), representing newly industrialized or developing economies, offer an intriguing context to examine trends, innovations and challenges in science education policy and practice.

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Contribution to the literature

- The study offers a comparative analysis of science education in BRICS countries, revealing shared challenges like resource limitations and innovative approaches such as inquiry-based learning. This comparison allows for the exchange of best practices and collaborative improvements in science teaching globally.
- The review underscores the importance of adapting science education to local cultural and socioeconomic contexts, challenging the universal applicability of educational reforms and advocating for policies that respect local realities.
- The study points out the need for more research on cultural responsiveness and the integration of indigenous knowledge in science education, setting a clear agenda for future investigations to make science teaching more inclusive and relevant.

Several studies have analyzed science education in individual BRICS countries, providing valuable localized insights. For instance, Ramnarain (2014) studied the implementation of inquiry-based science education in South Africa, while Zhao et al. (2023) examined science teachers' professional knowledge in China. However, there remains a need for a systematic synthesis of research on this topic across BRICS collective. As Daus et al. (2019) notes, cross-national comparisons enable the sharing of best practices and identification of systemic weaknesses in science education. Moreover, the cultural, socioeconomic and policy variations between BRICS countries provide a rich backdrop to illuminate convergences and divergences in educational priorities and outcomes (Carnoy et al., 2016).

This systematic review aims to analyze peer-reviewed studies on science education policies, practices, challenges, and innovations across BRICS countries. Synthesizing insights from diverse cultural and developmental contexts can highlight shared goals, effective pedagogies, and systemic barriers in improving science education. The outcomes of this research can inform policymakers seeking to enhance science learning outcomes and align educational initiatives with sustainable development needs. It also has theoretical implications on the applicability of generalized best practices versus localized solutions in science education across varying national contexts.

LITERATURE REVIEW

BRICS organization, comprising Brazil, Russia, India, China, and South Africa, is conceptualized in international relations as a club that emulates the incumbent world powers. It operates informally to enhance its bargaining power and influence global economic governance. Motivated by common aversions to the dominance of the G7 nations, especially the USA, and challenges to their autonomy, BRICS countries strive for a greater voice within existing multilateral institutions, including major international financial organizations. They also explore establishing parallel multilateral institutions. Notably, China's disproportionate strength within this club has led to a dominance in internal decisions, reflecting a dynamic like the USA' role within the G7 (Cynthia et al., 2017). This brief overview offers an insight into the foundational principles and operational dynamics of BRICS organization. The member countries, representing emerging economies, have come together to assert their collective interests and influence in the global arena, particularly in matters of economic governance and international finance (Streltsov et al., 2021).

Education in BRICS countries is similar in terms of the challenges they face, such as the need for quality, inclusiveness, and equality (Wolhuter, 2023). They have also experienced an increase in international research collaboration and production of international collaborative publications, with varying degrees of growth and improvement in research quality and impact (Fan et al., 2022). Additionally, legal education in BRICS countries has undergone modifications due to globalization, with common influences from the USA and the UK education systems and a focus on improving quality and affordability (Chang et al., 2018; Vinnichenko & Gladun, 2018). On the other hand, there are differences in the specific goals, objectives, structure, and quality of legal education in each country, influenced by factors such as ideology, economic development, and proximity to Eastern or Western models (Chang et al., 2018). Furthermore, the impact of tertiary education on economic development varies among BRICS countries, with different levels of causality and effects of academic and vocational training programs.

Science education in BRICS countries has seen significant growth and development in recent years. The top research universities in BRICS countries have actively participated in international research collaborations, leading to an increase in the production of international collaborative publications. China and India have shown rapid improvement and enhancement in the research quality and impact of their international cooperation in scientific publications (Fan et al., 2022). The expansion of higher education in BRICS countries, including Brazil, Russia, India, and China, has resulted in a larger pool of university graduates, including engineers and computer scientists, which may have implications for the future development of the global knowledge economy (Gorelova et al., 2021; Kovalev & Shcherbakova, 2019). BRICS countries are actively involved in exporting education, allowing an increasing number of foreign citizens to study in their higher education institutions (Carnoy et al., 2013). Overall, science education in BRICS countries is experiencing growth and international collaboration, which may have long-term effects on the global scientific landscape.

Science Education BRICS Countries

Science education in Brazil has gone through many reforms, yet quality and equity issues persist. National curricular parameters established in the late 1990s promoted constructivist science teaching approaches, but ineffective implementation impeded lasting improvements (Costin & Pontual, 2020). While national assessments show strong improvement in science scores since 2005, performance remains unequal across regions and socioeconomic strata. Science without borders program has achieved considerable results, but the structure of unequal regional access to scholarships and fellowships remains unchanged (Barbosa et al., 2022). Teachers face systemic challenges like lacking infrastructure, inadequate teacher training (Ribas Rodrigues & dos Santos, 2019) and minimal practical application of scientific concepts (Ferreira et al., 2013). However, promising programs such as hands-on science seek to improve science instruction through emphasizing experimentation and inquiry-based techniques aligned with students' contexts (Ferreira et al., 2022). Embedding science education within local cultures and addressing persistent inequities remain priorities for Brazil to develop its future scientific capacity (Gurgel et al., 2016).

Science education in Russia has strong foundations in research and theory but faces challenges in translating this to engaging classroom practices. The Soviet legacy focused on fundamental scientific concepts and principles, which continues to shape curricula today. However, this theoretical orientation often lacks integration with practical application and inquiry-based pedagogies (Lisichkin & Leenson, 2013). Assessment-driven cultures further constrain opportunities for creative scientific exploration among students (Fuller, 2013). Recent efforts support more student-centered learning through quality teacher training and integrating digital technologies (Anisimova, 2021). But systemic change remains gradual. Sustained reforms towards hands-on, contextualized science instruction are essential for Russia to develop talent and innovation aligned with the demands of the 21st century global STEM economy.

Science education in India aims to cultivate scientific temperament and research acumen, but continued gaps in quality and access remain barriers. Following independence, policies focused on strengthening science and math education to build national scientific capabilities (Sonam, 2019; Tandon, 2019). 2005 national curriculum framework brought progressive reforms aligning science pedagogies with inquiry, creativity, and application (Koul, 2019; Saha et al., 2015). However, limitations persist due to insufficient resources, large class sizes, standardized testing pressures, and lack of contextualization to students' lives (Roy & Roy, 2021). Quality science instruction is often restricted to elite, urban schools, with rural and lower-income regions lagging (Kulshreshtha et al., 2022). Initiatives to improve teacher training, integrate technology, and promote localized and interactive science teaching seek to transform science education across communities enabling India to harness its full potential.

Science education in China emphasizes a rigorous academic foundation and achievement on high-stakes exams, with recent efforts to integrate more student-centered pedagogies (Yang & Lin, 2016). Chinese students consistently rank top globally in standardized assessments like PISA, indicative of a strong grasp of scientific concepts and principles (Yang & Fan, 2023). However, critics argue this reflects rote learning rather than critical analysis or creativity (Gong et al., 2022). Recent curriculum reforms aim to foster scientific inquiry through quality teacher training, hands-on experimentation, and inquiry-based learning aided by technology (Ong et al., 2020; Yang et al., 2019). However, enduring obstacles remain because of cultures that prioritize examinations, classrooms that are filled, and instructional models that are centered around the teacher (Lingbiao, 2013; Liu et al., 2015). Sustaining changes that develop students' passionate curiosity and engagement with science remains an ongoing pursuit in Chinese education.

Science education in South Africa continues to face difficulties due to unequal systems, necessitating comprehensive reforms to align both quality and accessibility (Louw & Verwey, 2000). There were significant disparities between well-endowed white schools and underprivileged black schools (Mpisi & Alexander, 2022). The process of democratization has resulted in changes in the curriculum, with the aim of enhancing critical thinking and science education that is applicable to the local context (Amin & Mahabeer, 2021; Tagutanazvo & Bhagwandeen, 2022). Nonetheless, challenges persist due to deficiencies in infrastructure, teachers' expertise, and students' backgrounds (Dhurumraj & Moola, 2023; Schulze & van Heerden, 2015; Xaba & Sondlo, 2022). Various initiatives concentrate on enhancing teacher professional development, integrating indigenous knowledge, and implementing inquiry-based science teaching methods to transform educational outcomes (Soares et al., 2021). However, substantial improvements in learning environments, resources, and access to high-quality science instruction are still required to bridge the enduring divides.

In conclusion, this review highlights common goals as well as persistent challenges across BRICS nations to elevate science education and cultivate future scientific talent. While country contexts vary, shared priorities emerge on improving quality of instruction, promoting inquiry-based and hands-on pedagogies, integrating technology, and enhancing teacher training. However, systemic inequities in access and outcomes remain barriers, exacerbated by resource constraints, assessment-driven cultures, and limitations in making science locally relevant. Tensions persist between global standards and local needs. Addressing these complex challenges requires comprehensive reforms tailored to national and community contexts. As BRICS countries cooperate strategically amidst shifting global paradigms, they have much to gain from collaborating to enhance science education policy and practice. Synthesizing insights and innovations can accelerate collective progress. With coordinated efforts, BRICS nations can strengthen science education to unlock their full socio-economic potential and contribute to the global knowledge economy.

METHODOLOGY

This systematic review aims to synthesize and analyze relevant literature in a methodologically rigorous and reproducible manner (Siddaway et al., 2019). The methodology adopted for this review is designed to ensure the comprehensive collection, evaluation, and synthesis of available studies pertinent to our research question. This section outlines the systematic approach employed in the identification, selection, and analysis of relevant literature, emphasizing the adherence to established protocols and standards in systematic reviews (Rethlefsen et al., 2021). The process commenced with a structured search across multiple databases, including Scopus, Web of Science (WoS), and ERIC, to capture a broad spectrum of relevant literature. The subsequent phases involved meticulous screening and selection procedures to refine the pool of articles, ensuring their relevance and quality. These steps included an initial screening based on titles and abstracts, followed by a full-text review and application of specific inclusion and exclusion criteria. Notably, the geographical scope of the studies was a critical factor, focusing on works related to or inclusive of BRICS nations. Through this methodological framework, the review aims to provide transparent and replicable procedures, contributing to the reliability and validity of the findings and enabling future researchers to build upon this work.

Data Collection Process for Systematic Review Study

This systematic review followed a structured data collection process based on PRISMA to ensure the comprehensiveness and relevance of the included studies (Rethlefsen et al., 2021). The process encompassed several stages, as detailed below:

Initial database search

The initial search was conducted across three databases: Scopus, WoS, and ERIC. This search yielded a total of 407 relevant articles distributed, as follows: Scopus (169 articles), WoS (51 articles), and ERIC (187 articles).

Screening of titles & abstracts

The articles from each database were then screened based on their titles and abstracts. This screening process was vital to exclude publications that were not pertinent to the study's scope. The screening resulted in a reduced number of relevant articles: 28 from WoS, 43 from ERIC, and 63 from Scopus.

Removal of duplicates

After consolidating the data from all three databases, duplicate entries were identified and removed. This step was crucial to ensure the uniqueness of each study in the review. Post-duplication removal, 74 unique articles remained for further analysis.

Full-text analysis & inclusion criteria

The full texts of these 74 articles were then accessed for detailed examination. Two key criteria were used to determine their inclusion in the final analysis:

1. **Relevance level:** The articles were assessed for their relevance to the study's focus.
2. **Geographical scope:** Articles focusing on or including data from countries outside BRICS nations (Brazil, Russia, India, China, and South Africa) were excluded. In cases, where the data encompassed multiple countries, articles were excluded if the relevance to BRICS nations was unclear.

Classification & advanced analysis

55 articles (listed in **Appendix A**) were classified based on the country of focus, allowing for a country-specific analysis. This classification facilitated further advanced analyses to derive comprehensive insights pertinent to the systematic review's objectives.

Data Analysis

The data underwent an initial process of decontextualization to prepare them for analysis. This involved extracting relevant passages from their original

Table 1. Categories & code definition

Category	Code	Description
Study context	Teaching methods	Focus on various teaching approaches, methodologies, & practices. Prevalent across multiple entries.
	Challenges in teaching	Discusses challenges in teaching, especially in science education.
	Perceptions	Focuses on perceptions of teachers, students, & other stakeholders.
	Science education	Addresses science teaching, indicating significant interest.
	Integration of indigenous knowledge	Highlights inclusion of indigenous knowledge in teaching.
Pedagogical approach	Inquiry-based learning	Emphasizes fostering inquiry & exploration in science.
	Collaborative learning	Highlights group work & collaborative activities.
	Integration of technology	Mentions using digital technologies & ICT in teaching.
	Hands-on activities	Emphasizes practical work for experiential learning.
	Contextualized learning	Focuses on making science education relevant to students' lives & cultures.
	Critical pedagogy	Highlights importance of critical thinking in science education.
	Culturally responsive teaching	Includes indigenous knowledge & culturally specific models.
	Professional development for teachers	Focuses on enhancing teachers' skills through development programs.
Challenges	Resource & material constraints	Related to insufficient resources or materials.
	Teacher & student challenges	Relates to challenges faced by teachers ^ students.
	Scientific content & inquiry	Challenges with nature & delivery of scientific content.
	Learning & education issues	General challenges in learning process or educational system.
	Cultural & contextual barriers	Challenges arising from cultural differences or context-specific issues.
	Methodological difficulties	Relates to teaching methodologies or instructional strategies.
Key findings	Science education & learning	Focus on science education & learning processes.
	Role of teachers & students	Highlights importance of teachers & students in educational process.
	Scientific understanding & knowledge	Themes related to acquisition & enhancement of scientific knowledge.
	Challenges in education	Findings related to difficulties in science education.
	Methodological approaches	Focus on specific educational methodologies or approaches.
	Effectiveness & impact	Relates to effectiveness of educational strategies or teaching methods.

sources to allow for an impartial examination of their content. Afterwards, a stage of recontextualization occurred, wherein the extracted content was re-evaluated in the context of the surrounding data to ensure the accurate capture of meanings (Lester et al., 2020).

Next, open coding was employed on the decontextualized data. Each data point was carefully reviewed and assigned codes that represented core concepts (Strauss & Corbin, 1998). These codes were developed inductively, allowing for the emergence of categories that were grounded in the data rather than based on preconceived theories. The initial coding framework was continuously refined through constant comparison, whereby newly coded data were consistently compared with existing codes to ensure consistency and to identify new thematic strands (Ruggiano & Perry, 2019).

Following this, axial coding was conducted to organize the codes into categories and subcategories, thereby elucidating the relationships between them (Strauss & Corbin, 1998). This stage involved a process of classification that was both inductive and deductive, guided by the research questions and the theoretical framework, while also remaining receptive to unexpected insights from the data (Patton, 2002).

Selective coding was then performed to integrate and refine the categories into a coherent framework that encompasses the central phenomena under investigation (Strauss & Corbin, 1998). This caused the creation of a thematic structure (**Table 1**) that not only addressed the pedagogical approaches, challenges, and contexts of science education in BRICS countries but also uncovered the complex interplay between educational policies, cultural norms, and teaching practices (Braun & Clarke, 2006).

Throughout the analysis process, trustworthiness was ensured through methodological rigor. This included triangulation of data sources, peer debriefing, and member checks, which served to establish the credibility and reliability of the findings (Carter et al., 2014). The resulting narrative offers a comprehensive and contextually grounded understanding of the complexities surrounding science education within BRICS consortium, with implications for policy, practice, and future research endeavors.

FINDINGS

The studies related to science education in BRICS countries have been examined in four categories. The first category involves analyzing the context and topic of the studies, examining where and how they were conducted. The second category focuses on pedagogical approaches and teaching methods, addressing key research questions in the field. The third category examines the challenges associated with science education. Finally, the fourth category delves into the main findings and conclusions of the research.

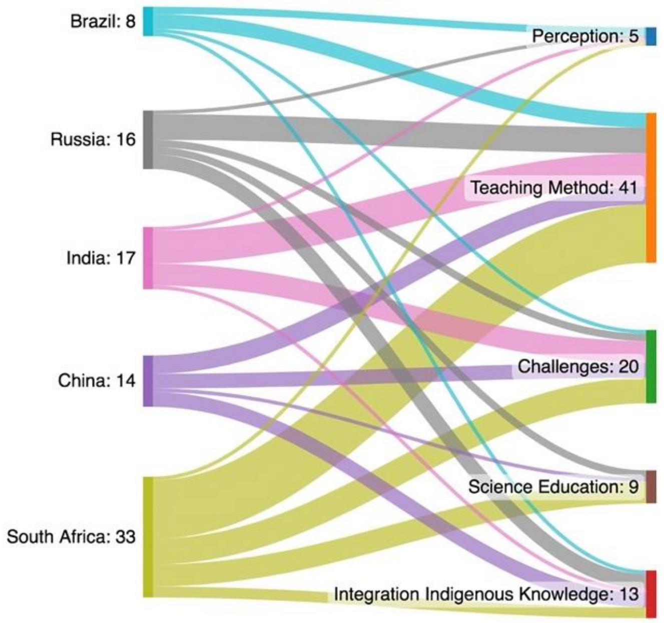

Figure 1. Study context & topics based on country (Source: Authors' own elaboration)

Study Context & Topics

Across different countries, there is a notable emphasis on teaching methods and science education (**Figure 1**). For instance, articles like Petrus (2018) and Ramnarain and Rudzirai (2020) from South Africa highlight a focus on teaching methodologies, which is a recurring theme in other countries as well. This indicates a global interest in enhancing educational pedagogy, particularly in the context of science education.

The dataset shows that educational challenges are a focus in some studies but not universally. This variation likely reflects the diverse educational landscapes and specific issues prevalent in each country. For example, the article by Akuma and Callaghan (2019) delves into extrinsic challenges in education, a theme that may not be as prominent in other countries. This suggests that while there are global concerns in education, each country also has its unique challenges that are influenced by its specific context. Another study by Xue and Li (2022) related to challenges on interdisciplinary activities in science teaching.

An intriguing aspect revealed in the analysis is the inclusion of indigenous knowledge, as exemplified by articles such as Opoku and James (2021). However, this topic is not consistently observed in all studies, suggesting it may be more relevant in countries with a substantial indigenous heritage and cultural background. The examination of whether local knowledge sources are integrated into science education, to varying degrees in each country, offers insights into the cultural and societal priorities of each nation's educational research.

Science education is a shared area of interest among various countries, but the approach to this subject differs widely. These variations reflect the distinct educational systems, curriculum emphases, and research priorities in each country. For instance, the study (John, 2019) focuses on the teaching methodologies in physical sciences, which may vary in both approach and content compared to similar studies in other nations. In contrast, another study by Sumatokhin and Kalinova (2016) concentrates specifically on biology research.

The area with the least amount of research conducted is in the field of perception. Studies measuring the perceptions of various stakeholders in science education have targeted different groups. For example, the study by Ribas Rodrigues and dos Santos (2019) investigated the perceptions of school science teachers, while the study by Petrus (2018) focused on examining the perceptions of both teachers and students.

In conclusion, the dataset provides a comparative view of educational research priorities and methodologies across various countries. It highlights shared interests in teaching methods and science education, while also pointing out unique focal points like indigenous knowledge integration and country-specific educational challenges. Each study, with its unique context and focus, contributes to a broader understanding of the global educational research landscape.

Pedagogical Approach

In analyzing the pedagogical approaches used in science teaching across BRICS countries, several interesting similarities and differences emerge (**Figure 2**). A common trend across these countries is the emphasis on collaborative learning and hands-on activities. This similarity suggests a shared understanding of the value of interactive and experiential learning in science education. For instance, South Africa (e.g., articles by Akuma & Callaghan, 2019; Ramnarain & Rudzirai, 2020) and Russia (e.g., articles by Anokhin et al., 2021; Malyuga & Petrosyan, 2022) show a significant inclination towards collaborative learning, while India (e.g., articles by Pareek, 2013; Pathare et al., 2018) stands out for its extensive use of hands-on activities. Such approaches are indicative of an educational focus that values student interaction and practical engagement in learning processes.

Another notable similarity is the Integration of Technology in the educational curriculum, particularly in China (e.g., Lee et al., 2014; Wang, 2022), Russia (e.g., Fedina et al., 2017; Vasilevna-Portnova, 2022), and India (e.g., Krishnan et al., 2016; Nandhakumar & Govindarajan, 2020). This indicates a movement towards incorporating modern digital tools and resources, reflecting a global trend in education towards embracing technology-enhanced learning.

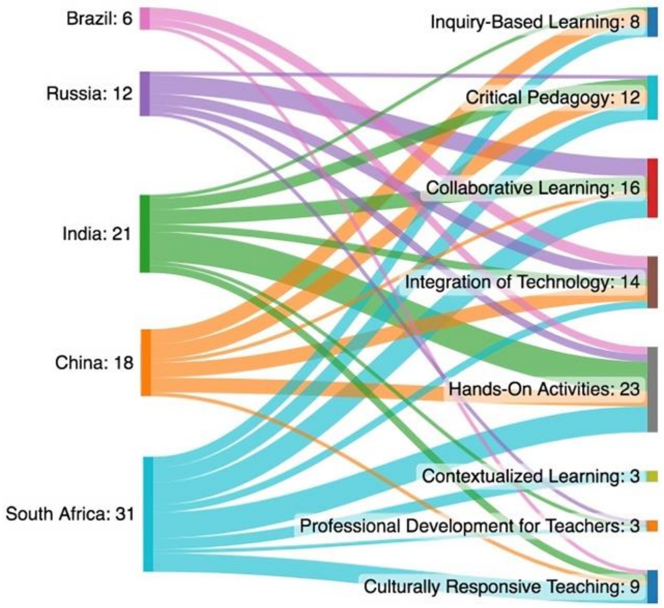

Figure 2. Pedagogical approach based on country (Source: Authors' own elaboration)

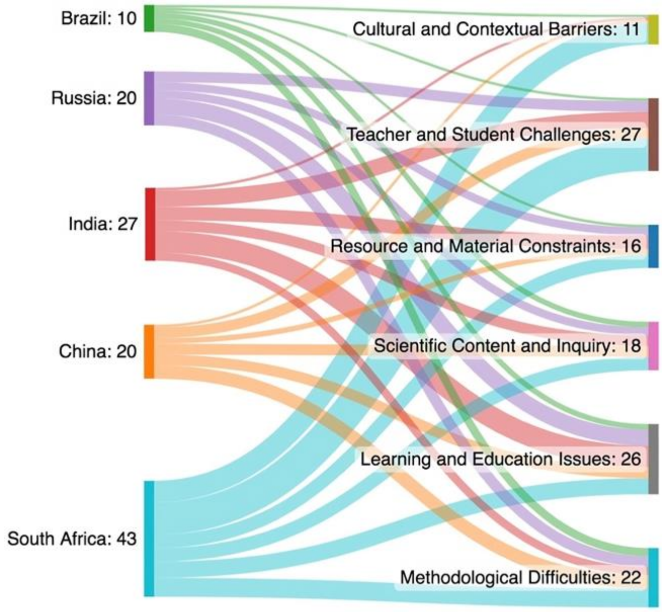

Figure 3. Challenges for science teaching based on country (Source: Authors' own elaboration)

However, differences in approaches are also prominent. India, with its highest number of hands-on activities, emphasizes practical engagement. This approach, supported by instances in articles like studies (Jennifer G. et al., 2022; Nandhakumar & Govindarajan, 2020) point towards a pedagogy that prioritizes experiential learning. India also maintains a balance with a significant number of instances in collaborative learning and integration of technology.

China's education system, as illustrated by articles like by Sang et al. (2012) and Xue and Li (2022), uniquely focuses on inquiry-based learning and critical pedagogy, along with integration of technology. This suggests a strong inclination towards fostering student-centered learning and critical thinking skills, a methodology that is less emphasized in the other BRICS countries. Russia's approach, predominantly seen in articles like by Malyuga and Petrosyan (2022) and Usak and Masalimova (2019), is characterized by a strong preference for collaborative learning, indicating a focus on group-based learning dynamics. However, it shows a lesser emphasis on methods like contextualized learning and culturally responsive teaching, which are more prevalent in other countries.

In the case of South Africa, a diverse approach is evident. As seen in articles such as Zenda (2017), there is a balance across various methods like hands-on activities, collaborative learning, and critical pedagogy. The notable use of contextualized learning, as in Oyoo (2017) and Schabort et al. (2018), might reflect an educational emphasis on making science education relevant to local or cultural contexts. Brazil, however, as indicated by a limited dataset, shows a focus on integration of technology and hands-on activities but lacks variety in pedagogical approaches compared to the other countries.

In summary, these insights demonstrate how each country within BRICS group has tailored its science education methodologies to suit its unique educational goals and cultural contexts. From India's emphasis on practical engagement to China's focus on inquiry and critical thinking, and South Africa's diverse pedagogical strategies, each country displays distinct educational priorities. This diversity, while showing some common threads, highlights the varied educational landscapes within these countries.

Challenges

The analysis of the challenges in science teaching across BRICS countries reveals both shared difficulties and distinct, country-specific issues (**Figure 3**). These insights are drawn from the article references provided in the dataset.

A common challenge faced across these countries is related to teacher and student dynamics. This is a significant concern in nations like India and South Africa, as evidenced by instances in articles such as Jennifer G. et al. (2022) and Zenda (2017). These instances highlight issues surrounding the preparedness, skill level, and interaction between teachers and students in the realm of science education. Another widely shared difficulty is learning and education issues, notably present in India and Russia, as seen in articles like by Balgopal et al. (2021) and Sumatokhin (2017). This suggests challenges in the broader educational context and learning environments, possibly reflecting systemic issues within educational frameworks or curriculums.

However, each country also faces unique challenges. India, for instance, places a notable emphasis on learning and education issues, as shown in articles like by Pareek (2013) and Sarkar et al. (2017). This may indicate deeper systemic challenges within its educational framework or curriculum, pointing to a need for structural reforms or enhancements.

In contrast, China's challenges are more evenly spread across various categories, including teacher and student challenges and scientific content and inquiry, as illustrated in Wan and Lee (2023) and Yao and Guo (2018). This balanced distribution of challenges suggests a need for a holistic approach to addressing the multifaceted difficulties in science education.

Russia, as demonstrated in articles such as by Anokhin et al. (2021) and Bortnik et al. (2021), is distinct for its focus on learning and education issues. This could indicate challenges in the educational system, perhaps in curriculum structure or the broader learning environment.

South Africa faces its unique set of challenges, especially in terms of cultural and contextual barriers, as highlighted in Meiring (2019) and Seehawer (2018). These challenges point to the importance of considering cultural and local contexts in science education, suggesting that educational methods and content need to be more aligned with the cultural and societal backdrop of the country.

Brazil's dataset indicates a spread across different challenges but with a generally lower frequency compared to other countries. Notable challenges include methodological difficulties and learning and education issues, as seen in articles like Ferreira et al. (2013). This suggests areas, where Brazil might need to focus on developing more robust methodologies and addressing systemic educational issues.

In summary, while issues like teacher and student dynamics and learning and education problems are common across BRICS nations, each country exhibits unique challenges that reflect its specific educational landscape and context. From India's systemic issues to South Africa's cultural and contextual barriers, these challenges highlight the diverse and complex nature of science teaching in different countries.

Key Findings & Conclusions

In the realm of science education research among BRICS nations, each country exhibits distinct priorities and areas of focus (**Figure 4**). Brazil stands out for its emphasis on 'scientific understanding and knowledge' (da Ressurreicão Brandão et al., 2023; Ferreira et al., 2013) contributing to a third of the total research in this category among BRICS nations. Additionally, Brazil shows a keen interest in 'methodological approaches' (da Silva et al., 2021; Ferreira et al., 2013), but it is relatively less engaged in addressing 'challenges in education' (Ribas Rodrigues & dos Santos, 2019) and assessing 'effectiveness and impact' (Ferreira et al., 2013).

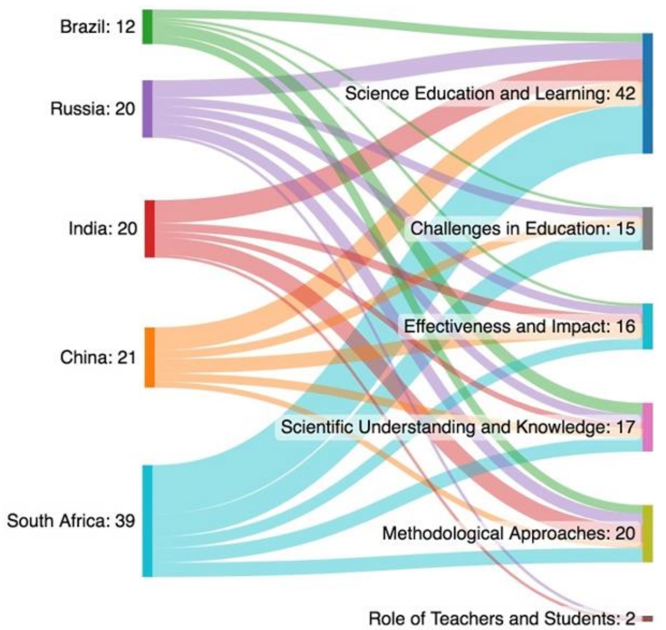

Figure 4. Key findings of studies based on country (Source: Authors' own elaboration)

China, on the other hand, leads in the 'science education and learning' (eight out of nine) category, accounting for over 38% of the total research in this area across BRICS. Chinese research also places a significant emphasis on the 'effectiveness and impact' (Lee et al., 2014; Sang et al., 2012) of educational practices, suggesting a focus on practical outcomes and results. However, it lags in areas like 'scientific understanding and knowledge' (three out of nine) and 'methodological approaches' (two out of nine).

India is notable for its balanced approach, with a strong focus on both 'science education and learning' (eight/12) and 'methodological approaches' (six/12). It is unique among BRICS for its attention to the 'role of teachers and students', indicating a more participatory approach to science education. However, India's contributions to 'scientific understanding and knowledge' and 'challenges in education' are relatively minimal.

Russia demonstrates a more evenly distributed focus across different categories. It is particularly attentive to 'challenges in education' and 'methodological approaches', reflecting a concern for both practical and theoretical aspects of science education. This balanced approach is also visible in its attention to 'scientific understanding and knowledge' and 'effectiveness and impact'.

Lastly, South Africa leads strongly in 'science education and learning' (17/18), accounting for nearly 44% of the total research in this area among BRICS countries. It also significantly addresses 'Challenges in

Education', more than any other BRICS country. However, like Brazil, it shows less engagement in 'methodological approaches' and 'effectiveness and impact'.

Overall, while there is a shared emphasis on 'science education and learning' across BRICS, each country displays unique patterns in its research focus. These patterns reflect the diverse educational priorities and contexts in which these countries operate, ranging from practical applications and outcomes to methodological and pedagogical innovations.

DISCUSSION

This systematic review offers valuable insights into the state of science education across five BRICS nations. The analysis reveals several key trends, challenges, and areas of convergence and divergence.

One major finding is the shared emphasis on improving teaching methodologies and pedagogical approaches to science education across all BRICS countries. As noted by Akuma and Callaghan (2019), Ramnarain and Rudzirai (2020), and Ribas Rodrigues and Santos (2019), there is significant interest in enhancing instructional techniques, with a focus on collaborative, hands-on, inquiry-based, and technology-integrated learning. This aligns with literature highlighting the need to move away from traditional didactic teaching models towards more interactive, student-centered pedagogies in science education globally (Prinsloo, 2016; Tytler, 2020). However, the degree of adoption of progressive techniques is varied, with countries like India strongly utilizing hands-on activities (Pareek, 2013; Pathare et al., 2018) while others like China emphasize critical thinking approaches (Sang et al., 2012; Xue & Li, 2022). Contextual factors shape the prioritization of pedagogies in each country.

The analysis also illuminates common systemic challenges impeding science education quality across BRICS nations. As noted in studies by Balgopal et al. (2021), Sumatokhin (2017), and Zenda (2017) persisting issues with teacher preparedness, student engagement, and broader educational frameworks obstruct reforms and learning outcomes. This aligns with literature pointing out limited instructional time, large class sizes, standardized testing pressures, and lack of resources as key barriers in developing countries (Prinsloo, 2016; Tytler, 2020). However, cultural, and contextual blockers, like in South Africa (Meiring, 2019; Seehawer, 2018), also require localized solutions.

Furthermore, the review demonstrates that priorities in science education research differ among BRICS countries based on specific goals. Brazil focuses more on content knowledge and methodologies (da Ressurreicão Brandão et al., 2023; Ferreira et al., 2013) while China emphasizes evaluating interventions and learning processes (Lee et al., 2014; Sang et al., 2012). India uniquely highlights the role of teachers and students (Pareek, 2013), whereas South Africa leads in addressing systemic challenges (Zenda, 2017). As Carnoy et al. (2013) discussed, variations between BRICS countries shape educational emphases.

Nonetheless, the analysis reveals science education policy and practice remain entrenched in traditional academic structures in many BRICS countries, with reforms gradually taking root. Despite intentions to nurture scientific skills and inquiry-based learning, assessment-focused systems persist, as do limitations in teacher training, resources, and local contextualization, as noted in studies across all five countries. This demonstrates that transforming science education to align with 21st century imperatives is an unfinished process requiring sustained, systemic efforts in BRICS nations.

Therefore, the review emphasizes that while common goals and challenges exist, improving science education in BRICS countries will necessitate tailored interventions responding to localized needs within each unique context. At the same time, sharing best practices and innovations between BRICS nations can catalyze progress across borders. As Heras and Ruiz-Mallen (2017) note, cross-national comparisons enable identifying effective policies and systemic weaknesses. Through cooperation, BRICS countries can learn from each other's science education reform efforts while designing context-specific solutions.

Further research can support these goals by addressing gaps identified in the review, such as limited engagement with cultural responsiveness and indigenous knowledge in science pedagogies across BRICS countries, as well as minimal comparative analysis of educational outcomes. As BRICS bloc evolves amidst global power shifts, cooperation in science education policy and practice will be vital to collectively advance innovation and sustainable development capabilities.

CONCLUSIONS

This systematic review offers a synthesis of research on policies, practices, challenges, and innovations in science education across five BRICS countries. The analysis reveals several key insights into the trends and priorities shaping science teaching and learning in these major emerging economies. The review highlights common goals across BRICS nations to improve the quality of science education through enhanced teacher training, student-centered pedagogies, technology integration and inquiry-based learning. However, systemic challenges like resource constraints, assessment-driven cultures, and lack of local contextualization persist and impede reforms. While shared challenges exist, the analysis also illuminates country-specific barriers shaped by cultural and developmental contexts. Moreover, variations are evident in research foci and pedagogical orientations between countries, demonstrating localized priorities. This suggests that while best practices may be shared across borders, improving science education requires tailored interventions responding to each nation's unique needs and barriers. Developing context-specific solutions while learning from other BRICS countries can accelerate collective progress.

However, this review has some limitations. The search was restricted to three databases and English language publications, which excludes potentially valuable literature. There was also limited comparative analysis of educational outcomes across BRICS countries. Moreover, the review did not investigate gender, racial and socioeconomic equity issues within science education in each context. To address these limitations, future research should expand the search across more regional databases and in multiple languages. Comparative analyses of instructional time, curriculum content, assessments, and learning outcomes can offer richer insights into variations. Exploring cultural responsiveness and integration of indigenous knowledge in science pedagogies could illuminate innovative directions. Investigating diversity, inclusion and equity metrics can reveal critical gaps impeding access to quality science education.

As BRICS nations cooperate strategically to advance innovation and sustainable development capabilities, transforming science education policy and practice will be critical. While countries adopt global best practices, they must also craft context-specific solutions responsive to local cultures, values, and developmental needs. Sustained improvements require addressing systemic inequities and reorienting assessment-driven structures towards nurturing curiosity, critical thinking, and creativity.

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REFERENCES

Akuma, F. V., & Callaghan, R. (2019). Characterizing extrinsic challenges linked to the design and implementation of inquiry-based practical work. *Research in Science Education, 49*(6), 1677-1706. https://doi.org/10.1007/s11165-017-9671-x

Amin, N., & Mahabeer, P. (2021). Curriculum tinkering in situations of crises and inequalities: The case of South Africa. *Prospects, 51*(1-3), 489-501. https://doi.org/10.1007/s11125-021-09564-8

Anisimova, T. I. (2021). Forming bachelors' labor actions in teacher training when studying disciplines of mathematical and natural science cycle. *International Electronic Journal of Mathematics Education, 10*(3), 157-165. https://doi.org/10.29333/iejme/298

Anokhin, E. O., Aleshin, G. Y., Tishkin, A. A., Korolev, V. V., Sobol, A. G., Evdokimov, K. M., & Chepiga, A. A. (2021). Not great, not terrible: Distance learning of chemistry in Russian secondary schools during COVID-19. *Chemistry Teacher International, 3*(4), 349-357. https://doi.org/10.1515/cti-2020-0016

Bajpai, S., Asif, S. S., & Akhtar, S. A. (2016). Electromagnetic education in India. *Comparative Professional Pedagogy, 6*(2), 60-66. https://doi.org/10.1515/rpp-2016-0020

Balgopal, M. M., Gerardo, N. M., Topden, J., & Gyatso, K. (2021). Moving past postcolonial hybrid spaces: How Buddhist monks make meaning of biology. *Science Education, 105*(3), 473-497. https://doi.org/10.1002/sce.21616

Bansal, G. (2021). Indian pre-service teachers' conceptualizations and enactment of inquiry-based science education. *Education 3-13, 49*(3), 275-287. https://doi.org/10.1080/03004279.2020.1854957

Bansal, G. (2022). The hegemony of English in science education in India: A case study exploring impact of teacher orientation in translating policy in practice. *Cultural Studies of Science Education, 17*(2), 439-466. https://doi.org/10.1007/s11422-021-10068-2

Barbosa, R. S., Adefila, A., & Garcia, M. L. T. (2022). Entrenched disadvantage and the internationalization of education: A review of the science without border program in Brazil. *Education Policy Analysis Archives, 30*, 171. https://doi.org/10.14507/EPAA.30.7211

Bortnik, B., Stozhko, N., & Pervukhina, I. (2021). Context-based testing as an assessment tool in chemistry learning on university level. *Education Sciences, 11*(8), 450. https://doi.org/10.3390/educsci11080450

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101. https://doi.org/10.1191/1478088706qp063oa

Carnoy, M., Khavenson, T., Loyalka, P., Schmidt, W. H., & Zakharov, A. (2016). Revisiting the relationship between international assessment outcomes and educational production: Evidence from a longitudinal PISA-TIMSS sample. *American*

Educational Research Journal, 53(4), 1054-1085. https://doi.org/10.3102/0002831216653180

Carnoy, M., Loyalka, P., & Froumin, I. (2013). University expansion in the BRIC countries and the global information economy. *Change: The Magazine of Higher Learning, 45*(4), 36-43. https://doi.org/10.1080/00091383.2013.806196

Carter, N., Bryant-Lukosius, D., Dicenso, A., Blythe, J., & Neville, A. J. (2014). The use of triangulation in qualitative research. *Oncology Nursing Forum, 41*(5), 545-547. https://doi.org/10.1188/14.ONF.545-547

Chang, V., Chen, Y., & Xiong, C. (2018). Dynamic interaction between higher education and economic progress: A comparative analysis of BRICS countries. *Information Discovery and Delivery, 46*(4), 225-238. https://doi.org/10.1108/IDD-07-2018-0023

Costin, C., & Pontual, T. (2020). Curriculum reform in Brazil to develop skills for the twenty-first century. In F. M. Meimers (Ed.), *Audacious education purposes: How governments transform the goals of education systems* (pp. 47-64). Springer. https://doi.org/10.1007/978-3-030-41882-3_2

Cynthia, R., Armijo, L., & Katada, S. (2017). *Introduction: The BRICS as a club*. Oxford University Press. https://doi.org/10.1093/oso/9780190697518.003.0001

da Ressurreicão Brandão, M. A., do Rego Barros Bello, M. E., de Souza, M. F., de Jesus Carvalho, M. R., & Maciel, B. M. (2023). Food safety knowledge among 7th-grade middle school students: A report of a Brazilian municipal school using workshop-based educational strategies. *Food Science and Nutrition, 11*(10), 6447-6458. https://doi.org/10.1002/fsn3.3587

da Silva, K. F., de Oliveira, R. D. V. L., & Soares, M. H. F. B. (2021). The ludic and human rights: The anti-racist fight in science education for a political-scientific formation through graffiti art. *Acta Scientiae* [*Journal of Science*], *23*(6), 237-269. https://doi.org/10.17648/ACTA.SCIENTIAE.6324

Daus, S., Nilsen, T., & Braeken, J. (2019). Exploring content knowledge: Country profile of science strengths and weaknesses in TIMSS. Possible implications for educational professionals and science research. *Scandinavian Journal of Educational Research, 63*(7), 1102-1120. https://doi.org/10.1080/00313831.2018.1478882

Dhurumraj, T., & Moola, Z. (2023). Exploring teacher improvisation and its influence on learner performance in an under-resourced grade 11 life science class. *International Journal of Research in Business and Social Science (2147-4478), 12*(2), 384-392. https://doi.org/10.20525/ijrbs.v12i2.2341

Fan, X., Liu, H., Wang, Y., Wan, Y., & Zhang, D. (2022). Models of internationalization of higher education in developing countries–A perspective of international research collaboration in BRICS countries. *Sustainability, 14*(20), 13659. https://doi.org/10.3390/su142013659

Fedina, O. V., Zakinyan, A. R., & Agibova, I. M. (2017). Design of science laboratory sessions with magnetic fluids. *International Journal of Mechanical Engineering Education, 45*(4), 349-359. https://doi.org/10.1177/0306419017708644

Ferreira, C., Baptista, M., & Arroio, A. (2013). Teachers' pedagogical strategies for integrating multimedia tools in science teaching. *Journal of Baltic Science Education, 12*(4), 509-524. https://doi.org/10.33225/jbse/13.12.509

Ferreira, D. M., Sentanin, F. C., Parra, K. N., Negrao Bonini, V. M., De Castro, M., & Kasseboehmer, A. C. (2022). Implementation of inquiry-based science in the classroom and its repercussion on the motivation to learn chemistry. *Journal of Chemical Education, 99*(2), 578-591. https://doi.org/10.1021/acs.jchemed.1c00287

Fuller, M. B. (2013). An empirical study of cultures of assessment in higher education. *Education Leadership Review, 14*(1), 20-27.

Gilyazova, O. S., Zamoshchanskii, I. I., & Zamoshchanskaya, A. N. (2020). A liberal arts and sciences education at the Russian higher school: Concept, formats, benefits, and limitations. *Perspektivy Nauki i Obrazovania* [*Perspectives Sciences and Education*], *46*(4), 10-22. https://doi.org/10.32744/pse.2020.4.1

Gong, Z., Soomro, S. A., Nanjappan, V., & Georgiev, G. V. (2022). The gap in design creativity education between China and developed countries. *Proceedings of the Design Society, 2*, 871-880. https://doi.org/10.1017/pds.2022.89

Gorelova, G. G., Shibanova, E. K., Nechaeva, S. V., & Zakharova, T. N. (2021). BRICS countries education export: Challenges and forecasts. *KnE Social Sciences, 5*(2), 37-45. https://doi.org/10.18502/kss.v5i2.8332

Gurgel, I., Pietrocola, M., & Watanabe, G. (2016). The role of cultural identity as a learning factor in physics: A discussion through the role of science in Brazil. *Cultural Studies of Science Education, 11*(2), 349-370. https://doi.org/10.1007/s11422-014-9580-5

Heras, M., & Ruiz-Mallén, I. (2017). Responsible research and innovation indicators for science education assessment: How to measure the impact? *International Journal of Science Education, 39*(18), 2482-2507. https://doi.org/10.1080/09500693.2017.1392643

Hewson, M. G. (2012). Traditional healers' views on their indigenous knowledge and the science curriculum. *African Journal of Research in Mathematics, Science and Technology Education, 16*(3), 317-332. https://doi.org/10.1080/10288457.2012.10740748

James, A. A., Beni, S., & Stears, M. (2019). Teaching science in the foundation phase: Where are the gaps and how are they accounted for? *South African Journal of Childhood Education, 9*(1), a759. https://doi.org/10.4102/sajce.v9i1.759

Jennifer G., A., Thomas, M. G., & Solomon, R. V. (2022). Does virtual titration experiment meet students' expectation? Inside out from Indian context. *Journal of Chemical Education, 99*(3), 1280-1286. https://doi.org/10.1021/acs.jchemed.1c01034

John, M. (2019). Physical sciences teaching and learning in eastern cape rural schools: Reflections of pre-service teachers. *South African Journal of Education, 39*, S1-S12. https://doi.org/10.15700/saje.v39ns1a1660

Kavai, P., de Villiers, R., Fraser, W., Sommerville, J., & Strydom, N. (2015). Animal organ dissections in high schools: Is there more than just cutting? *African Journal of Research in Mathematics, Science and Technology Education, 19*(2), 143-155. https://doi.org/10.1080/10288457.2015.1049011

Kavai, P., Villiers, R., & Fraser, W. (2017). Teachers' and learners' inclinations towards animal organ dissection and its use in problem-solving. *International Journal of Instruction, 10*(2), 39-54. https://doi.org/10.12973/iji.2017.1023a

Koul, R. (2019). Addressing diversity in Indian science classrooms. In *Science education in India* (pp. 129-142). Springer. https://doi.org/10.1007/978-981-13-9593-2_7

Kovalev, I., & Shcherbakova, A. (2019). BRICS cooperation in science and education. *Strategic Analysis, 43*(6), 532-542. https://doi.org/10.1080/09700161.2019.1669903

Krishnamoorthy, R. (2023). Intra-action analysis of emergent science phenomena: Examining meaning-making with the more than human in science classrooms. *Cultural Studies of Science Education, 18*, 853-877. https://doi.org/10.1007/s11422-023-10148-5

Krishnan, M. S., Brakaspathy, R., & Arunan, E. (2016). Chemical education in India: Addressing current challenges and optimizing opportunities. *Journal of Chemical Education, 93*(10), 1731-1736. https://doi.org/10.1021/acs.jchemed.6b00231

Kulshreshtha, P., Gupta, S., Shaikh, R., Aggarwal, D., Sharma, D., & Rahi, P. (2022). Foldscope embedded pedagogy in STEM education: A case study of SDG4 promotion in India. *Sustainability, 14*(20), 13427. https://doi.org/10.3390/su142013427

Lee, K. T., Chalmers, C., Chandra, V., Yeh, A., & Nason, R. (2014). Retooling Asian-Pacific teachers to promote creativity, innovation and problem solving in science classrooms. *Journal of Education for Teaching, 40*(1), 47-64. https://doi.org/10.1080/02607476.2013.864017

Lester, J. N., Cho, Y., & Lochmiller, C. R. (2020). Learning to do qualitative data analysis: A starting point. *Human Resource Development Review, 19*(1), 94-106. https://doi.org/10.1177/1534484320903890

Liang, B. (2017). The problem of science education in minority areas–Based on a study in Gansu Province of China. *Chinese Education and Society, 50*(1), 18-24. https://doi.org/10.1080/10611932.2016.1262183

Lingbiao, G. (2013). Reforms in student assessment in Mainland China. In E. Hau-Fai Law, & C. Li (Eds.), *Curriculum innovations in changing societies* (pp. 449-472). Sense Publishers. https://doi.org/10.1007/978-94-6209-359-1_25

Lisichkin, G. V., & Leenson, I. A. (2013). Natural-sciences education in secondary school in the USSR and Russia: History, trends, and challenges of modernization. *Russian Journal of General Chemistry, 83*(6), 1185-1203. https://doi.org/10.1134/S1070363213060388

Liu, E., Liu, C., & Wang, J. (2015). Pre-service science teacher preparation in China: Challenges and promises. *Journal of Science Teacher Education, 26*(1), 29-44. https://doi.org/10.1007/s10972-014-9404-1

Louw, G., & Verwey, S. (2000). The South African new educational environment: Turbulent change in tertiary institutions. *Communicare* [*Communicate*], *19*(1), 78-94. https://doi.org/10.36615/jcsa.v19i1.1838

Malyuga, E. N., & Petrosyan, G. O. (2022). Effective integration of distance courses through project-based learning. *Frontiers in Education, 6*. https://doi.org/10.3389/feduc.2021.788829

Mavuru, L., & Ramnarain, U. (2020). Learners' socio-cultural backgrounds and science teaching and learning: A case study of township schools in South Africa. *Cultural Studies of Science Education, 15*(4), 1067-1095. https://doi.org/10.1007/s11422-020-09974-8

Meiring, L. F. (2019). Foundation phase science teacher identity: Exploring evolutionary module development to promote science teaching self-efficacy. *South African Journal of Childhood Education, 9*(1), a603. https://doi.org/10.4102/sajce.v9i1.603

Moiseev, V. V, & Chernyh, S. A. (2019). Actual problems of education and science in Russia. *Advances in Economics, Business and Management Research, 96*, 504-508. https://doi.org/10.2991/icemse-19.2019.117

Mpisi, A., & Alexander, G. (2022). Social identity formation of Black learners in South African historically white schools. In *Education applications & developments VII* (pp. 74-84). https://doi.org/10.36315/2022ead07

Msimanga, A., & Lelliott, A. (2014). 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*(7), 1159-1183. https://doi.org/10.1080/09500693.2013.851427

Mtsi, N., & Maphosa, C. (2016). Challenges encountered in the teaching and learning of the natural sciences in rural schools in South Africa. *Journal of Social Sciences, 47*(1), 58-67. https://doi.org/10.1080/09718923.2016.11893544

Mudaly, R., Pithouse-Morgan, K., van Laren, L., Singh, S., & Mitchell, C. (2015). Connecting with pre-service teachers' perspectives on the use of digital technologies and social media to teach socially relevant science. *Perspectives in Education, 33*(4), 23-41.

Nandhakumar, R., & Govindarajan, K. (2020). Effect of database technology on some cognitive variables in learning of physics at undergraduate level. *TOJET: The Turkish Online Journal of Educational Technology, 19*(4), 75-83.

Ong, E. T., Luo, X., Yuan, J., & Yingprayoon, J. (2020). The effectiveness of a professional development program on the use of STEM-based 5E inquiry learning model for science teachers in China. *Science Education International, 31*(2), 179-184. https://doi.org/10.33828/sei.v31.i2.7

Opoku, M. J., & James, A. (2021). Pedagogical model for decolonizing, indigenizing, and transforming science education curricula: A case of South Africa. *Journal of Baltic Science Education, 20*(1), 93-107. https://doi.org/10.33225/jbse/21.20.93

Oyoo, S. O. (2017). Learner outcomes in science in South Africa: Role of the nature of learner difficulties with the language for learning and teaching science. *Research in Science Education, 47*(4), 783-804. https://doi.org/10.1007/s11165-016-9528-8

Pareek, R. B. (2013). An assessment of availability and utilization of laboratory facilities for teaching science at secondary level. *Science Education International, 30*(1), 75-81. https://doi.org/10.33828/sei.v30.i1.9

Pathare, S., Huli, S., Ladage, S., & Pradhan, H. C. (2018). Understanding first law of thermodynamics through activities. *Physics Education, 53*, 025013. https://doi.org/10.1088/1361-6552/aa9de7

Patton, M. Q. (2002). Two decades of developments in qualitative inquiry. *Qualitative Social Work, 1*(3), 261-283. https://doi.org/10.1177/1473325002001003636

Petrus, R. M. (2018). A comparison of teachers' and students' perceptions of the factors contributing to poor performance in physical sciences: A case of South Africa. *Journal of Turkish Science Education, 15*(4), 93-103.

Prinsloo, E. H. (2016). The role of the humanities in decolonizing the academy. *Arts and Humanities in Higher Education, 15*(1), 164-168. https://doi.org/10.1177/1474022215613608

Ramnarain, U. D. (2014). Teachers' perceptions of inquiry-based learning in urban, suburban, township and rural high schools: The context-specificity of science curriculum implementation in South Africa. *Teaching and Teacher Education, 38*, 65-75. https://doi.org/10.1016/j.tate.2013.11.003

Ramnarain, U. D., & Rudzirai, C. (2020). Enhancing the pedagogical practice of South African physical sciences teachers in inquiry-based teaching through empowerment evaluation. *International Journal of Science Education, 42*(10), 1739-1758. https://doi.org/10.1080/09500693.2020.1778810

Rethlefsen, M. L., Kirtley, S., Waffenschmidt, S., Ayala, A. P., Moher, D., Page, M. J., Koffel, J. B., Blunt, H., Brigham, T., Chang, S., Clark, J., Conway, A., Couban, R., de Kock, S., Farrah, K., Fehrmann, P., Foster, M., Fowler, S. A., Glanville, J., …, & Young, S. (2021). PRISMA-S: An extension to the PRISMA statement for reporting literature searches in systematic reviews. *Systematic Reviews, 10*(1), 1-19. https://doi.org/10.1186/s13643-020-01542-z

Ribas Rodrigues, M. I., & dos Santos, L. R. (2019). Conceptions of science teachers about the use of ICT in teaching practice: Challenges for science education in Brazil. *Prometeica* [*Promethean*], *19*, 58-71. https://doi.org/10.34024/prometeica.2019.19.9460

Roy, B., & Roy, A. (2021). Conducting examinations in India: Emergency, contention and challenges of students amidst covid-19 pandemic. *Children and Youth Services Review, 120*, 105768. https://doi.org/10.1016/j.childyouth.2020.105768

Ruggiano, N., & Perry, T. E. (2019). Conducting secondary analysis of qualitative data: Should we, can we, and how? *Qualitative Social Work, 18*(1), 81-97. https://doi.org/10.1177/1473325017700701

Saha, A., Nazar, M., Udaynarayanpur, B., & Mahavidyalaya, M. (2015). National curriculum framework for teacher education, 2009: A review of its perspectives and relevanceness. *International Journal of Applied Research, 1*(9), 776-778.

Sang, G., Valcke, M., van Braak, J., Zhu, C., Tondeur, J., & Yu, K. (2012). Challenging science teachers' beliefs and practices through a video-case-based intervention in China's primary schools. *Asia-Pacific Journal of Teacher Education, 40*(4), 363-378. https://doi.org/10.1080/1359866X.2012.724655

Sarkar, S., Mohapatra, S., & Sundarakrishnan, J. (2017). Assessing impact of technology based digital equalizer program on improving student learning outcomes. *Education and Information Technologies, 22*(1), 195-213. https://doi.org/10.1007/s10639-015-9434-0

Sattor, K., Islombek, A., Adhamjon, K., Zayniddin, J., Shavkat, Y., & Isroiljon, U. (2022). The role of the integration of science, education, and production in the training of personnel for construction educational areas. *Science and Innovation International Scientific Journal, 1*(8), 1040-1045. https://doi.org/10.5281/zenodo.7447731

Schabort, F., Sinnes, A., & Kyle, W. C. (2018). From contextual frustrations to classroom transformations: Female empowerment through science education in rural South Africa. *Educational Action Research, 26*(1), 127-143. https://doi.org/10.1080/09650792.2017.1286996

Schulze, S., & van Heerden, M. (2015). Learning environments matter: Identifying influences on the motivation to learn science. *South African Journal of Education, 35*(2), 1-9. https://doi.org/10.15700/saje.v35n2a1058

Seehawer, M. (2018). South African science teachers' strategies for integrating indigenous and western knowledges in their classes: Practical lessons in decolonization. *Educational Research for Social Change, 7*(SPE), 91-110. https://doi.org/10.17159/2221-4070/2018/v7i0a7

Siddaway, A. P., Wood, A. M., & Hedges, L. V. (2019). How to do a systematic review: A best practice guide for conducting and reporting narrative reviews, meta-analyses, and meta-syntheses. *Annual Review of Psychology, 70*, 747-770. https://doi.org/10.1146/annurev-psych-010418-102803

Soares, D., Lopes, B., Abrantes, I., & Watts, M. (2021). The initial training of science teachers in African countries: A systematic literature review. *Sustainability, 13*(10), 5459. https://doi.org/10.3390/su13105459

Sonam, T. (2019). Incubating western science education in Tibetan Buddhist monasteries in India. In *Science education in India* (pp. 27-45). Springer. https://doi.org/10.1007/978-981-13-9593-2_2

Strauss, A., & Corbin, J. (1998). *Basics of qualitative research techniques*. SAGE.

Streltsov, E. S., Rozhin, A. A., Vosiev, S. S., & Kosnikov, S. N. (2021). The economic potential of the BRICS countries as a challenge to modern world realities. *Propósitos y Representaciones* [*Purposes and Representations*], *9*(SPE3), e1143. https://doi.org/10.20511/pyr2021.v9nspe3.1143

Sumatokhin, S. V. (2017). Textbooks for biology applied in schools in Russia. *Journal of Subject Didactics, 2*(1), 61-66. https://doi.org/10.5281/zenodo.1238998

Sumatokhin, S. V., & Kalinova, G. S. (2016). Biology studies in Russian schools. *Journal of Subject Didactics, 1*(2), 127-132. https://doi.org/10.5281/zenodo.438179

Tagutanazvo, P. O., & Bhagwandeen, R. (2022). Developing strategies for teaching critical thinking in physical sciences learners at selected schools in Mashishila circuit in Mpumalanga Province, South Africa. In *Proceedings of the 14th International Conference on Education and New Learning Technologies* (pp. 5407-5407). https://doi.org/10.21125/edulearn.2022.1277

Tandon, M. (2019). History of science in India: Focus on pre-vedic and vedic times. In *Science education in India* (pp. 3-26). Springer. https://doi.org/10.1007/978-981-13-9593-2_1

Teck, Y., Lim, K., Lavonen, J., Kulshreshtha, P., Gupta, S., Shaikh, R., Aggarwal, D., Sharma, D., & Rahi, P. (2022). Foldscope embedded pedagogy in STEM education: A case study of SDG4 promotion in India. *Sustainability, 14*(20), 13427. https://doi.org/10.3390/su142013427

Tytler, R. (2020). STEM education for the twenty-first century. In J. Anderson, & Y. Li (Eds.), *Integrated approaches to STEM education: An international perspective* (pp. 21-43). Springer. https://doi.org/10.1007/978-3-030-52229-2_3

Usak, M., & Masalimova, A. R. (2019). Mentoring on science teacher education in Russia and international perspectives. *Journal of Baltic Science Education, 18*(3), 320-322. https://doi.org/10.33225/jbse/19.18.320

Vasilevna-Portnova, I. (2022). Russian scientific-animalistic images of the 20th century in the collection of biological museums. Their specific structure and meaning. *Arte, Individuo y Sociedad* [*Art, Individual and Society*], *34*(4), 1517-1542. https://doi.org/10.5209/aris.79969

Vinnichenko, O., & Gladun, E. (2018). Legal education in the BRICS countries in the context of globalization: A comparative analysis. *BRICS Law Journal, 5*(3), 4-39. https://doi.org/10.21684/2412-2343-2018-5-3-4-39

Wan, D., & Lee, Y. J. (2023). Engineering in grades 1-9 science education standard from China. *Science and Education*. https://doi.org/10.1007/s11191-023-00457-0

Wang, Y. (2022). Effects of augmented reality game-based learning on students' engagement. *International Journal of Science Education, Part B:*

Communication and Public Engagement, 12(3), 254-270. https://doi.org/10.1080/21548455.2022.2072015

Wolhuter, C. C. (2023). Education in the BRICS countries and the likely impact of the COVID-19 pandemic. *BRICS Journal of Economics, 4*(1), 131-146. https://doi.org/10.3897/brics-econ.4.e100736

Xaba, N., & Sondlo, A. (2022). Using a learner-based activity approach in developing science teachers' readiness in inquiry-based learning. In *Education and new developments* (pp. 340-343). https://doi.org/10.36315/2022v1end077

Xue, E., & Li, J. (2022). Contextualizing the philosophy of science education: Insight from China. *Educational Philosophy and Theory*. https://doi.org/10.1080/00131857.2022.2111256

Yan, S., Sun, D., Zhou, Q., Yang, Y., & Tian, P. (2023). Exploring the impact of virtual laboratory with KWL reflective thinking approach on students' science learning in higher education. *Journal of Computing in Higher Education*. https://doi.org/10.1007/s12528-023-09385-y

Yang, F., & Lin, J. (2016). A Chinese Tai Chi model: An integrative model beyond the dichotomy of student-centered learning and teacher-centered learning. *Asian Education Studies, 1*(2), 44. https://doi.org/10.20849/aes.v1i2.61

Yang, W., & Fan, G. (2023). Delving into the development of Chinese students based on PISA scores. In D. Guo (Ed.), *The frontier of education reform and development in China* (pp. 107-128). Springer. https://doi.org/10.1007/978-981-19-6355-1_7

Yang, W., Liu, C., & Liu, E. (2019). Content analysis of inquiry-based tasks in high school biology textbooks in Mainland China. *International Journal of Science Education, 41*(6), 827-845. https://doi.org/10.1080/09500693.2019.1584418

Yao, J. X., & Guo, Y. Y. (2018). Core competences and scientific literacy: The recent reform of the school science curriculum in China. *International Journal of Science Education, 40*(15), 1913-1933. https://doi.org/10.1080/09500693.2018.1514544

Zenda, R. (2017). Essential teaching methods to enhance learner academic achievement in physical sciences in rural secondary schools. *Information and Learning Science, 118*(3/4), 170-184. https://doi.org/10.1108/ILS-03-2017-0014

Zhao, G., Zhao, R., Li, X., Duan, Y., & Long, T. (2023). Are preservice science teachers (PSTs) prepared for teaching argumentation? Evidence from a university teacher preparation program in China. *Research in Science and Technological Education, 41*(1), 170-189. https://doi.org/10.1080/02635143.2021.1872518

APPENDIX A: LIST OF STUDIES

Table A1. List of studies

Code	Author	Country	Title
1	Akuma and Callaghan (2019)	South Africa	Characterizing extrinsic challenges linked to the design and implementation of inquiry-based practical work
2	Anokhin et al. (2021)	Russia	Not great, not terrible: Distance learning of chemistry in Russian secondary schools during COVID-19
3	Bajpai et al. (2016)	India	Electromagnetic education in India
4	Balgopal et al. (2021)	India	Moving past postcolonial hybrid spaces: How Buddhist monks make meaning of biology
5	Bansal (2021)	India	Indian pre-service teachers' conceptualizations and enactment of inquiry-based science education
6	Bansal (2022)	India	The hegemony of English in science education in India: A case study exploring impact of teacher orientation in translating policy in practice
7	Bortnik et al. (2021)	Russia	Context-based testing as an assessment tool in chemistry learning on university level
8	da Ressurreicão Brandão et al. (2023)	Brazil	Food safety knowledge among 7th-grade middle school students: A report of a Brazilian municipal school using workshop-based educational strategies
9	da Silva et al. (2021)	Brazil	The ludic and human rights: The anti-racist fight in science education for a political-scientific formation through graffiti art
10	Fedina et al. (2017)	Russia	Design of science laboratory sessions with magnetic fluids
11	Ferreira et al. (2013)	Brazil	Teachers' pedagogical strategies for integrating multimedia tools in science teaching
12	Gilyazova et al. (2020)	Russia	A liberal arts and sciences education at the Russian higher school: Concept, formats, benefits, and limitations
13	Gurgel et al. (2016)	Brazil	The role of cultural identity as a learning factor in physics: A discussion through the role of science in Brazil
14	Hewson (2012)	South Africa	Traditional healers' views on their indigenous knowledge and the science curriculum
15	James et al. (2019)	South Africa	Teaching science in the foundation phase: Where are the gaps and how are they accounted for?
16	Jennifer G. et al. (2022)	India	Does virtual titration experiment meet students' expectation? Inside out from Indian context
17	John (2019)	South Africa	Physical sciences teaching and learning in eastern cape rural schools: Reflections of pre-service teachers
18	Kavai et al. (2015)	South Africa	Animal organ dissections in high schools: Is there more than just cutting?
19	Kavai et al. (2017)	South Africa	Teachers' and learners' inclinations towards animal organ dissection and its use in problem-solving
20	Krishnamoorthy (2023)	India	Intra-action analysis of emergent science phenomena: Examining meaning-making with the more than human in science classrooms
21	Krishnan et al. (2016)	India	Chemical education in India: Addressing current challenges and optimizing opportunities
22	Lee et al. (2014)	China	Retooling Asian-Pacific teachers to promote creativity, innovation and problem solving in science classrooms
23	Liang (2017)	China	The problem of science education in minority areas–Based on a study in Gansu Province of China
24	Malyuga and Petrosyan (2022)	Russia	Effective integration of distance courses through project-based learning
25	Mavuru and Ramnarain (2020)	South Africa	Learners' socio-cultural backgrounds and science teaching and learning: A case study of township schools in South Africa
26	Meiring (2019)	South Africa	Foundation phase science teacher identity: Exploring evolutionary module development to promote science teaching self-efficacy
27	Moiseev and Chernyh (2019)	Russia	Actual problems of education and science in Russia
28	Msimanga and Lelliott (2014)	South Africa	Talking science in multilingual contexts in South Africa: Possibilities and challenges for engagement in learners home languages in high school classrooms

Table A1 (Continued). List of studies

Code	Author	Country	Title
29	Mtsi and Maphosa (2016)	South Africa	Challenges encountered in the teaching and learning of the natural sciences in rural schools in South Africa
30	Mudaly et al. (2015)	South Africa	Connecting with pre-service teachers' perspectives on the use of digital technologies and social media to teach socially relevant science
31	Nandhakumar and Govindarajan (2020)	India	Effect of database technology on some cognitive variables in learning of physics at undergraduate level
32	Opoku and James (2021)	South Africa	Pedagogical model for decolonizing, indigenizing, and transforming science education curricula: A case of South Africa
33	Oyoo (2017)	South Africa	Learner outcomes in science in South Africa: Role of the nature of learner difficulties with the language for learning and teaching science
34	Pareek (2013)	India	An assessment of availability and utilization of laboratory facilities for teaching science at secondary level
35	Pathare et al. (2018)	India	Understanding first law of thermodynamics through activities
36	Petrus (2018)	South Africa	A comparison of teachers' and students' perceptions of the factors contributing to poor performance in physical sciences: A case of South Africa
37	Ramnarain and Rudzirai (2020)	South Africa	Enhancing the pedagogical practice of South African physical sciences teachers in inquiry-based teaching through empowerment evaluation
38	Ribas Rodrigues and dos Santos (2019)	Brazil	Conceptions of science teachers about the use of ICT in teaching practice: Challenges for science education in Brazil
39	Sang et al. (2012)	China	Challenging science teachers' beliefs and practices through a video-case-based intervention in China's primary schools
40	Sarkar et al. (2017)	India	Assessing impact of technology based digital equalizer program on improving student learning outcomes
41	Sattor et al. (2022)	Russia	The role of the integration of science, education, and production in the training of personnel for construction educational areas
42	Schabort et al. (2018)	South Africa	From contextual frustrations to classroom transformations: Female empowerment through science education in rural South Africa
43	Seehawer (2018)	South Africa	South African science teachers' strategies for integrating indigenous and western knowledges in their classes: Practical lessons in decolonization
44	Sumatokhin (2017)	Russia	Textbooks for biology applied in schools in Russia
45	Sumatokhin and Kalinova (2016)	Russia	Biology studies in Russian schools
46	Teck et al. (2022)	India	Foldscope embedded pedagogy in STEM education: A case study of SDG4 promotion in India
47	Usak and Masalimova (2019)	Russia	Mentoring on science teacher education in Russia and international perspectives
48	Vasilevna-Portnova (2022)	Russia	Russian scientific-animalistic images of the 20^{th} century in the collection of biological museums. Their specific structure and meaning
49	Wan and Lee (2023)	China	Engineering in grades 1-9 science education standard from China
50	Wang (2022)	China	Effects of augmented reality game-based learning on students' engagement
51	Xue and Li (2022)	China	Contextualizing the philosophy of science education: Insight from China
52	Yan et al. (2023)	China	Exploring the impact of virtual laboratory with KWL reflective thinking approach on students' science learning in higher education
53	Yang et al. (2019)	China	Content analysis of inquiry-based tasks in high school biology textbooks in Mainland China
54	Yao and Guo (2018)	China	Core competences and scientific literacy: The recent reform of the school science curriculum in China
55	Zenda (2017)	South Africa	Essential teaching methods to enhance learner academic achievement in physical sciences in rural secondary schools