Teaching physical sciences in South African rural high schools: Learner and teacher views about the challenges

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Our study investigates the challenges encountered by learners and teachers of physical sciences in rural schools, specifically in the Joe Gqabi district of South Africa. We utilised self-study and constructivism theories in rural settings to examine the complex challenges for physical sciences in rural schools. In an interpretivist qualitative research methodology, we purposefully selected four rural high schools for our study, involving four physical sciences teachers and twelve learners. Interviewing served as the primary means of data collection, with thematic analysis of the acquired data. Our findings uncovered several challenges, including a lack of resources and laboratories, poor teaching, the abstract nature of the curriculum, large class sizes, and language difficulties, among others, encountered by both teachers and learners of physical sciences in rural schools. We offer significant information for policymakers, school managers, and the stakeholders in basic education, for creating specific actions and policies that support equitable educational opportunities and enhance the quality of physical sciences education in rural areas. We ask government to augment its funding in rural schools by allocating more resources and improving infrastructure.

Introduction

Rural high schools frequently have distinctive challenges regarding teaching and learning physical sciences, which affect both learners and teachers. It is crucial to effectively transmit scientific knowledge in these contexts to cultivate a strong foundation in STEM (science, technology, engineering, and mathematics) education. This foundation is essential for students' overall development and competitiveness in a world increasingly driven by technology. Nevertheless, the unequal distribution of educational resources, the geographical seclusion of rural areas, and the restricted access to innovative teaching methods provide considerable challenges for students and teachers in these environments. Despite several efforts to improve educational results, learners still underperform in physical sciences, especially in rural areas (Mabasa & Singh, 2020). Rural schools frequently suffer from a shortage of education resources and support systems necessary for effective physical science instruction. As a result, students in these schools experience a decline in their academic performance (Wang et al., 2020). Moreover, the lack of skilled teachers and insufficient opportunities for professional growth hinder the standard of physical science teaching in rural high schools (Krakehl et al., 2020).

These constraints provide a quandary for both students, who find it difficult to succeed in physical sciences, and teachers, who struggle to provide high-quality teaching. Teachers often face various obstacles, such as limited resources (lack of access to modern laboratory equipment, textbooks, and other essential educational resources for effective teaching and learning of physical sciences), shortages and quality of teachers (rural areas struggle to attract and retain qualified physical science teachers, resulting in a lack of

subject matter expertise and teaching skills, leading to subpar teaching standards), lack of student engagement and relevance (disconnect between traditional curriculum content and the everyday experiences of rural students, causing disengagement and disinterest in the subject matter), and limited community involvement and awareness of the importance of STEM education, which further worsen the challenges faced by rural schools.

The absence of support from parents, local authorities, and community organisations impedes endeavours to improve the teaching and learning environment (Wang et al., 2020). In addition, teachers in rural areas may face isolation, limiting their chances for professional growth and cooperation. This, in turn, can affect student learning outcomes (Krakehl et al., 2020).

Although some studies have examined the difficulties encountered by students in rural STEM education (Krakehl et al., 2020; Viloria et al., 2021), there are limited studies that investigate the experiences, viewpoints, and professional development needs of teachers working in rural areas. Furthermore, there is a scarcity of empirical research that comprehensively examines the unique challenges and factors that influence the teaching and learning of physical sciences in rural high schools from the viewpoint of teachers and learners. Conducting such research is crucial to creating interventions and policies based on solid data specifically designed to meet the needs of rural areas.

Against this background, our study sought answers to the following research questions:

1. What are the perspectives of teachers and learners in South African rural high schools regarding the challenges they face in teaching and learning physical sciences?
2. How do the challenges teachers and learners experience affect the teaching and learning of physical sciences?
3. What strategies do teachers employ to engage and motivate rural learners in science learning to mitigate these challenges?

Literature review

Perspectives of challenges in the teaching and learning of physical sciences

Teaching physical sciences in rural high schools in South Africa presents challenges affecting learners and teachers. Various studies have emphasised the challenges teachers and students in rural schools face (Humphrey-Darkeh et al., 2022; Ngwenya et al., 2023). The constraints may include a lack of availability of resources such as science laboratories and instructional materials, inadequate opportunities for professional development for teachers, and socio-economic inequalities that impact student learning outcomes (Humphrey-Darkeh et al., 2022). Furthermore, rural schools teaching and learning environments are greatly influenced by factors such as the language used for instruction, cultural norms, and community support networks (Ngwenya et al., 2023). Teachers in rural schools may have challenges adjusting their teaching approaches to cater to the varied needs of learners, especially considering the constraints of poor infrastructure and low support (Febriana et al., 2018).

Learners may also face challenges to academic success due to factors such as poverty, limited exposure to STEM disciplines, and limited access to educational opportunities outside of the classroom (Zenda, 2017). The low implementation of cutting-edge pedagogical methods, such as inquiry-based learning and technology integration, worsens the predicament teachers and learners encounter in rural schools (Xaba & Sondlo, 2022). The lack of proficient teachers with specialised expertise in rural areas impedes the efficient provision of science education (Muremela et al., 2021).

Some studies highlight the importance of language in teaching and learning, especially in the sciences. In these disciplines, using different codes and the level of language competence are essential factors that greatly affect students' understanding (Le Cordeur & Tshuma, 2019; Maluleke et al., 2020). Overcoming language hurdles and deciphering scientific terminology are crucial to improving academic achievement in science disciplines (Kazeni, 2020). Bouck et al. (2018) stated that rural schools must address several concerns, including financial matters, curriculum development, teacher quality, and community involvement.

Strategies to enhance the teaching and learning of physical sciences

Research has suggested and examined several strategies to tackle teachers' and learners' challenges in rural schools and enhance science teaching in rural areas. An important strategy emphasised is implementing different methodologies to facilitate teaching and learning (Olawumi & Mavuso, 2022). Needs assessments can identify the insufficient resources and support for STEM in underprivileged rural schools (Mwembe et al., 2022). Using hands-on and inquiry-based learning methods can effectively captivate rural learners and improve their comprehension of the subject (Zinger et al., 2020). Offering learners the chance to carry out experiments, investigate real-life occurrences, and participate in problem-solving tasks helps cultivate curiosity and enhance conceptual comprehension.

By incorporating technology into science education, teachers may effectively address geographical limitations and allow rural students to access superior teaching materials and resources (Kormos & Wisdom, 2021)). Virtual laboratories and Internet-based simulations can enhance traditional classroom teaching and introduce students to advanced scientific principles (Shambare & Simuja, 2021). Partnerships with nearby community organisations, corporations, and scientific institutes can enhance the science curriculum and offer students genuine learning opportunities (Murphy, 2022). Field visits, guest lectures, and mentoring programs provide a connection between classroom education and practical applications in the sciences and opportunities for professional development for improving teaching techniques and expanding their understanding of the subject matter (Kunz et al., 2013).

Training workshops, online courses, and peer collaboration networks have the potential to enable teachers to effectively utilise novel teaching practices and adjust to the unique needs of students in rural areas. Acknowledging and integrating rural students' cultural backgrounds and experiences into the science curriculum promotes inclusion and student engagement (Anlimachie et al., 2023). Incorporating indigenous knowledge, cultural

practices, and specific instances into science teaching can enhance the relevance and applicability of the material to students' everyday experiences.

To cater for rural students' varied learning needs and preferences, teachers should seek adaptable teaching methods that can suit different learning styles and abilities (Devlin & McKay, 2019). Individualised instruction, collaborative learning, and small-group tasks can effectively target specific learning needs and enhance academic achievement for all students. Research has shown that cooperative teaching techniques effectively address the variations in high school science students' learning styles, resulting in enhanced physical sciences learning (Boateng & Mushayikwa, 2022; Boateng & Mushayikwa, 2018).

Theoretical framework

We utilised two theoretical frameworks, self-study theory and constructivism theory, to provide a guiding perspective for this investigation. According to Samaras (2002), self-study is when teachers carefully and analytically reflect on their acts and the circumstances surrounding those actions to enhance their professional practice with greater intentionality. Self-study may be a valuable tool for teachers in rural schools, where resources and professional development opportunities may be lacking. It allows teachers to analyse their teaching practices and pinpoint areas that need improvement (Samuel & Dudu, 2018). Teachers who engage in self-study can investigate and implement novel teaching methods, such as integrating art into science education or incorporating learner-based activities. Self-study may be highly influential in cultivating self-directed learning abilities and internal motivation for students in rural schools (Mokoena, 2022). Teachers may motivate students to overcome challenges and actively participate in science lessons by promoting autonomy.

Constructivism emphasises the proactive involvement of learners in shaping their understanding of the world through first hand experiences and thoughtful contemplation (Sümer, 2021). Constructivism offers a framework that recognises and appreciates students' different language and cultural backgrounds in rural schools. By using constructivist methodologies, teachers may establish educational settings that accommodate the distinct needs of students from diverse backgrounds, thus guaranteeing fairness in physical science teaching (Jalak & Nasri, 2019). Constructivism in science education is needed for inventive instructional approaches, especially in rural regions where constraints on resources are common (Harris & Hodges, 2018).

Methodology

Our study employed an interpretivist paradigm. Kivunja and Kuyini (2017) stated that within an interpretivist paradigm, the primary focus is understanding individuals and their subjective perspectives of the surrounding reality. We used an ethnographic research design because in rural schools it enables the investigation of several contextual elements that influence science teaching, including resource constraints, community customs, and socioeconomic circumstances. This design allowed us to effectively document the

viewpoints and opinions of the participants, emphasising their ability to act, their principles, and their ambitions about science education.

We employed purposive sampling to select four physical sciences teachers and twelve physical sciences learners in Grade 12. Maree (2015) defined purposive sampling as the deliberate selection of participants based on predetermined criteria relevant to a research issue.

Data was collected from face-to-face interviews using a semi-structured interview schedule (Appendix A and Appendix B). Interviews were conducted during the period 19 February to 22 March 2024, in the schools where the participants were employed and enrolled in the first quarter of the 2024 academic year. Before the interview, participants were guaranteed confidentiality and informed about the nature of the interview. The interviews were conducted with the participants' consent and audio recorded. Teacher interviews were conducted in English. However, the learner interviews were conducted in their local language (IsiXhosa) and transcribed into English by the first author. The transcripts were verified by a language expert for consistency. Each interview lasted for 30 minutes.

Data were stored in an Excel spreadsheet. We utilised Braun and Clarke's (2006) 6-step framework to analyse the data due to its explicit and practical structure for thematic analysis, which involves identifying patterns or themes in the data and understanding its meaning.

Quality assurance measures

Ensuring trustworthiness is of utmost importance in a qualitative study examining the difficulties teachers and learners encounter in physical science education in rural schools. To sustain quality assurance for our research, we utilised member checking with participants to verify our interpretations of the data (Korstjens & Moser, 2017). To improve the dependability of our findings, we implemented an audit trail to track research choices and data-collecting methods. We engaged in peer debriefing to examine interpretations and assure the dependability of the findings. To improve the generalisability of our study, we included comprehensive and extensive explanations of the research environment, participants, and data-collecting techniques. This enables readers to evaluate our results' applicability to their situations (Korstjens & Moser, 2017).

Ethical considerations

The research ethics, protocols, and research rules were adhered to. The Eastern Cape Department of Education provincial office was approached to obtain permission to conduct this study within schools under their jurisdiction. Once the necessary approval was acquired, meetings were scheduled with the school administrators. The participants were guaranteed that the interviews would remain confidential and that their identities would not be disclosed. The researchers invited the subjects to participate willingly, ensuring their rights were safeguarded.

Results

Learner biographic information

Tables 1 and 2 display the demographic information of the physical science learners, and teachers selected to participate in this study. The four schools selected for this study are located in rural regions, marked by low socioeconomic status and limitations with resource accessibility. The schools possess substantial learner enrolments, especially in Grade 12, which greatly strains teachers and facilities. Each school has a total enrolment ranging from 800 to 1200, with an average of approximately 900 per school.

Table 1: Profile of physical science learners (N=12)

Criteria	Learners	Frequency
Gender	Male	6
	Females	6
Age	17	2
	18	7
	19	3
Grade	12	12
Pseudonyms	SA1, SA2, SA3, SB1, SB2, SB3, SC1, SC2, SC3, SD1, SD2, SD3.	

The Grade 12 classes in these rural schools are significantly large, frequently surpassing the national average in learner enrolment. This establishes a demanding educational setting in which personalised attention for learners is limited. The classrooms frequently experience overcrowding and lack enough resources, such as textbooks and laboratory equipment, thus affecting the quality of instruction, particularly in physical sciences.

Table 2: Profile of physical sciences teachers

Teacher pseudonym	TA	TB	TC	TD
School	A	B	C	D
Gender	Male	Male	Female	Female
Age	28 years	34 years	49 years	30 years
Qualifications	BSc Educ.	BSc Educ.	BSc Educ.	BSc Educ.
Teaching experience	7 years	12 years	20 years	10 years
Subjects taught	Physical Sci. Grade 10-12	Physical Sci. Grade 10-12	Physical Sci. Grade 12	Physical Sci. Grade 10-11

The total number of teachers employed at the schools varies between 10 and 15, with an average teacher-to-learner ratio indicative of the higher-class sizes characteristic of rural regions. Each school employs between 1 and 2 teachers tasked with teaching Grade 10 to 12 physical sciences. In addition, these teachers may have additional subjects like mathematics and natural sciences. Class sizes for Grade 12 learners in physical sciences are substantial, varying from 40 to 95 learners per class. This figure markedly exceeds the provincial average when class sizes in well-resourced regions are often limited to 25 to 30

learners. National data indicates that average class sizes in South African public schools range from 30 to 35 learners per class, with rural schools sometimes surpassing these numbers due to resource limitations and shortage of skilled teachers.

Each of the four teachers, one from each of the four high schools, taught learners in Grade 12. They all possess the necessary qualifications to teach physical sciences in the Further Education and Training (FET) phase since they all possess a bachelor's degree in science education. All four teachers are South Africans, aged between 28 and 49 years, two males and two females. Each of the four teachers was assigned a pseudonym (Table 2). Twelve learners participated in the study with three representatives from each school. All the learners were in Grade 12 taking physical sciences as a subject. Six were male, six were female; all were South African, ages ranging from 17 to 19 years (Table 1).

Table 3: Generated themes and sub-themes

Research question	Generated themes	Generated sub-themes
1. What are the perspectives of teachers and learners in South African rural high schools regarding the challenges they face in the teaching and learning of physical sciences?	Theme 1: Teachers' and learners' views on the challenges they face in the teaching and learning of physical sciences	Abstract concepts and mathematical complexity Lack of resources and laboratories Language complexity Curriculum relevance Classroom environment Community engagement
2. How do the challenges teachers and learners experience affect the teaching and learning of physical sciences?	Theme 2: The influence of challenges on the teaching and learning of physical sciences	Limited hands-on learning opportunities Reduce learners' engagement and motivation Unequal learning opportunities Influence on teacher instruction Low academic performance
3. What strategies do teachers employ to engage and motivate rural learners in physical sciences to mitigate these challenges?	Theme 3: Teaching strategies employed by teachers	Utilisation of low-cost resources Integration of practical demonstrations Outdoor and field-based learning with extra classes Community collaboration and expert involvement Technology integration Culturally relevant curriculum and instruction

Theme 1: Teachers' and learners' views on the challenges they face in the teaching and learning of physical sciences

In education, the teaching and learning of physical sciences are a cornerstone in fostering scientific literacy and critical thinking among students. However, this endeavour is not without its challenges, both for teachers and learners. Theme 1 delves into the multifaceted landscape of these challenges, aiming to illuminate the perspectives of teachers and learners alike. Six sub-themes arose: (a) abstract concepts and mathematical

complexity; (b) lack of resources and laboratories; (c) language complexity; (d) curriculum relevance; (e) classroom environment; and (f) community engagement.

Abstract concepts and the mathematical complexity

During the learner interviews, participants believed that the abstract nature of physical science presents challenges for them due to the complexity of concepts, the mathematical complexity, and the need for critical thinking skills. One learner narrated:

> I struggle with physical science because of the abstract concepts and theories that are often difficult to grasp because I cannot observe or experience them in everyday life. For example, concepts like electricity and magnetism are not easily understood without a strong foundation in abstract thinking. (SC3).

In contrast to topics like geography, which deal with tangible and readily available facts, physical science frequently depends on indirect evidence and intricate mathematical models to elucidate natural occurrences. Some individuals may struggle to embrace scientific notions without concrete proof or firsthand observation. The interaction between abstract ideas and physical facts might result in misunderstandings and challenges while trying to comprehend scientific topics. One learner has expressed the following opinion:

> In physical science, my teacher expects me to think critically, often involving the application of abstract concepts to solve complex problems in electricity and magnetism. I find many other topics in chemistry to be very abstract and have a lot of calculations. (SB2).

This cognitive demand can be overwhelming for learners who are not accustomed to abstract thinking or struggle with analytical reasoning. Developing proficiency in critical thinking and problem-solving skills is essential for overcoming the abstract nature of physical science and succeeding in STEM disciplines.

Lack of resources and laboratories

All participants mentioned a lack of resources as one of the challenges they face in the teaching and learning of physical sciences in their schools. The following are some of their verbatim responses.

> Physical science is taught in classes using textbooks only, and these textbooks contain too much information. We cannot witness and test reactions by ourselves because we do not use a laboratory in this school (SA1).

> We have limited resources; for example, we share textbooks since we are many learners. We have never been exposed to laboratory work (SD3).
> Limited resources such as laboratories, learner support material, lack of internet access and inadequate tools from the Department of Education (TA).

Without these resources, it is difficult for learners to grasp concepts and teachers to teach effectively. This implies that physical sciences teaching and learning become difficult for both learners and teachers.

Language complexity

The language of instruction plays an important role in the learners' achievements. The language used in class during the lesson is important as it makes the learner understand what is taught. Both learners and teachers responded that there is a language barrier. Since the language of instruction is English, most learners find it difficult to communicate in English and find it challenging to understand instructions in English. Teacher responses included:

> There is a language barrier here. They have a problem, especially regarding understanding the sciences (TB).
> The language for teaching and learning is a barrier to learners' understanding of science concepts. I struggle to explain major science phenomena in English for learners to understand (TC).
> Learners cannot read and write with understanding. Language is a big factor in my school (TD).

Responses from teachers indicated that learners have problems with language. It is very difficult for them to interpret questions so that they can give the correct answers.

Curriculum relevance

The participants responded to the relevance of the physical sciences curriculum and its contents. They believed some topics were nice to teach, but some were very complex and difficult to comprehend. However, the participants had different perspectives regarding the curriculum and its relevance.

> If we want teaching and learning to improve, more emphasis must be placed on curriculum delivery because this is the lifeblood of schooling. (TD).

Curriculum structuring and planning may also experience some difficulties in rural areas. District officials are less likely to visit rural schools, indicating that the teacher is the mediator between the curriculum and the learners.

Classroom environment

The classroom environment entails the conditions in which teaching and learning take place. A good environment makes learning comfortable. Some teachers in rural schools teach in unfavourable conditions. Some participants voiced the following statements:

> Lack of classroom. We have broken windows and doors (TC).
> Our classroom is overcrowded. We sit together and share textbooks and limited personal study time (SB1).

Poor learning environments, such as overcrowded due to large class sizes, make teaching difficult. Learners in such classes cannot be easily controlled because the teacher cannot easily reach all of them. The effectiveness of assessment is also compromised.

Community engagement

In this section, we interpret learners' responses regarding their local community's role in assisting them with their physical science subject. These learners come from rural communities, which are often agricultural, with many relying on subsistence farming, livestock rearing, and small-scale agriculture as their primary sources of income. The participants highlighted existing community structures or informal networks that may facilitate learning. This includes support such as access to study resources, help with homework, involvement of community members with scientific knowledge, or opportunities for practical, science-related learning in the local environment. The participants mentioned the following regarding the support they received from their communities.

> I do not think the local community is involved in supporting me in my physical sciences education, not even my own parents (SA3).
> Nothing because teachers are providing the necessary information for education. I do not see anyone from the community assisting us. (SD2).
> The only way the local community can help is by getting help from the top post-matric learners (SC1).

This implies that it was very difficult for parents and other community members to be involved in the learners' learning activities in rural areas since most parents are illiterate.

Theme 2: The influence of challenges on the teaching and learning of physical sciences

The teaching and learning of physical sciences have always been subject to numerous challenges that significantly influence the effectiveness of education in this field. Five sub-themes emerged: (a) limited hands-on learning opportunities; (b) reduced learners' engagement and motivation; (c) unequal learning opportunities; (d) influence on teacher instruction; and (e) low learner academic performance.

Limited hands-on learning opportunities

When both learners and teachers were asked about the effect of the challenges they face at school on the teaching and learning of physical sciences, the teachers responded that without adequate laboratory equipment and materials, students miss out on valuable hands-on learning experiences essential for understanding science concepts. One teacher commented:

> Teaching physical sciences without resources and laboratories has a negative effect on my teaching and my learners' understanding (TB).

This assertion was concurred by two learners:

> I do not relate well with physical sciences content because we only read how to carry out experiments from textbooks. However, we never carry them out practically due to insufficient relevant resources (SC2).
> Since my teacher does not use these resources in teaching physical sciences, we find it difficult to understand complex topics in physical sciences (SD1).

Reduce learners' engagement and motivation

Most participants mentioned that lacking resources can lead to monotonous and uninspiring lessons, decreasing student engagement and motivation. Students may become disinterested in the subject if they perceive it as inaccessible or irrelevant to their lives due to the absence of hands-on experiences. Two learners share the following sentiments:

> We do not have Internet access in my school. We use traditional methods of learning, and teachers use only blackboards to teach us (SA1).
> My school has no technology resources; we only use textbooks, which does not engage us actively in the lesson. In fact, nothing is motivating me to do my best in physical sciences (SA2).

Unequal learning opportunities

The results from the teachers' and learners' interviews show that schools with limited resources may disproportionately affect students from disadvantaged backgrounds, exacerbating existing inequities in education. One teacher lamented:

> My learners in this rural school do not have the same access to quality physical science education as their peers in well-equipped schools. This can disadvantage those who aspire to pursue higher education or careers in science-related fields. Even if they pass matric, most of them do other non-science-related courses at the university (TA).

Unequal learning opportunities can contribute to a persistent achievement gap between rural and urban students in science. This may result in lower academic performance among rural students, impacting their educational attainment and future opportunities.

Limited extracurricular opportunities

Responses from teachers indicated that rural schools do not offer a broader range of extracurricular activities related to science, such as science clubs, competitions, and research opportunities. As a result, learners may have fewer opportunities to participate in these activities, limiting their exposure to real-world applications of scientific concepts and their ability to develop a passion for science. Rural schools often have fewer resources compared to urban schools, including laboratory equipment, textbooks, and technology. Limited access to these resources can hinder hands-on learning experiences and experimentation, which are crucial for understanding scientific concepts.

Influence on teacher instruction

When teachers were asked how the challenges they experienced when teaching physical sciences may impact their instruction, they collectively indicated that they struggle to illustrate concepts effectively and engage students without access to necessary resources. One teacher lamented:

> It has not been easy for me to teach some concepts without practical demonstrations. I can see in my learners' eyes that their knowledge does not connect to the experimental questions when taught only theoretically. They also get frustrated and lose their passion for physical science (TB).

Limited resources may force teachers to rely solely on traditional lecture-based instruction, which may not cater to diverse learning styles or foster deep understanding. As a result, rural students may not receive the same quality of instruction in physical science as their urban counterparts.

Low academic performance

When the participants were asked about the effect of the challenges they experience at the school level, they responded that the lack of resources can hinder students' ability to grasp fundamental concepts, leading to lower academic achievement in physical sciences. One learner and a teacher lamented:

> As I said earlier, my learners underperform in physical science at the matric level of almost everyone, and their performance is generally low instead of high. I have tried everything. However, I still do not have the resources to help me demonstrate some practical concepts to my learners. Do you blame me? (TA).

This can restrict students' exposure to higher-level scientific concepts and limit their opportunities for academic enrichment and preparation for post-secondary education.

> My physical science teacher did not major in physical science, so I heard. Most of the time, the class does not understand him. We, the learners, fail even controlled tests other than mid-year and final end-of-year examinations (SD2).

Students may struggle to perform well on assessments and standardised tests without adequate support and materials, limiting their future educational and career opportunities.

Theme 3: Teaching strategies employed by teachers

Six sub-themes emerged from this theme: (a) utilisation of low-cost resources; (b) integration of practical demonstrations; (c) outdoor and field-based learning; (d) community collaboration and expert involvement; (e) technology integration; and (f) culturally relevant curriculum and instruction.

Utilisation of low-cost resources

During the individual interviews, most participants indicated that they creatively utilise inexpensive or locally available materials to conduct experiments and demonstrations. They further indicated that they repurpose everyday items as science equipment or use natural materials in the surrounding environment for hands-on activities. Two teachers narrated during the individual interviews:

> As a teacher, I understand the importance of maximising resources, especially when faced with limitations. When traditional resources are scarce, I rely on creativity and innovation to effectively teach physical sciences. One strategy I employ is using low-cost materials that are easily accessible to both me and my learners. For instance, I often use everyday items like measuring cups, string, and balloons instead of expensive lab equipment to demonstrate concepts such as force and motion (TD).

> In teaching physical sciences amidst resource limitations, I design experiments and demonstrations requiring minimal resources but effectively illustrating key concepts. I use simple materials like aluminium foil, plastic bags, and thermometers to experiment with insulation and conduction (TB).

Integration of practical demonstrations

When participants were asked about strategies, they used to teach physical sciences when resources were limited, most responded that they integrate practical demonstrations in their classrooms. Two teachers have this to say:

> As a teacher, I believe in the power of practical demonstrations to enhance the learning experience. I might demonstrate principles of motion, and I strive to make the learning of physical sciences both accessible and engaging for all my learners (TA).

> In teaching physical sciences, I prioritise practical demonstrations as a fundamental aspect of the learning process. I use simple tools like magnets, springs, and rubber bands to demonstrate the principles of magnetism and elasticity (TB).

Outdoor and field-based learning with extra classes

When teachers were asked about strategies to mitigate the challenges they face in these schools, one teacher indicated that he took advantage of the rural environment and organised outdoor learning experiences to boost learners' morale in physical science. Allowing learners to explore scientific concepts firsthand in their natural surroundings fosters a deeper connection to the subject and promotes experiential learning.

However, most teachers indicated that they organise extra classes for the learners to provide opportunities for slower learners to get more practice.

Community collaboration and expert involvement

When the teachers were asked how they involve the community in science learning, they indicated that they collaborate with experts in the community to enrich science education by connecting learners with local resources, expanding their access to expertise, and fostering a culture of inquiry, exploration, and innovation. One teacher indicated:

> At the beginning of the year, at my school, we hold a tie ceremony and invite guest speakers to share their expertise and provide hands-on learning experiences, inspiring students and broadening their perspectives on science. These interactions have inspired many our learners, broadened their horizons, and reinforced the relevance of science education beyond the classroom (TC).

Some participants also indicated that they encouraged parental and familial involvement in science education to enhance students' learning experiences.

Technology integration

Despite limited access to technology, teachers creatively leverage resources such as smartphones, tablet computers, or community Internet facilities to integrate digital tools into science instruction. When the teachers were asked about integrating technology into science instruction, a few mentioned examples such as a WhatsApp group with their learners where they send videos on a specific topic for online watching, and using PowerPoint presentation slides to reemphasise certain concepts in physical sciences.

Culturally relevant curriculum and instruction

Culturally relevant curriculum and instruction is an educational approach that acknowledges and incorporates students' cultural backgrounds, experiences, and perspectives into the teaching and learning process. When teachers were asked about strategies to mitigate the challenges they face in their schools when teaching physical sciences, they gave varying responses indicating that some design curriculum materials, instructional methods, and learning experiences to resonate with rural learners' cultural context and lived experiences. One teacher shared:

> As a teacher in a rural school, I recognise that rural communities often have unique cultural backgrounds and perspectives that shape students' experiences and understanding of the world. By incorporating elements of students' culture into the curriculum, I can make science more relatable and meaningful to them. For example, I may integrate local examples, traditional knowledge, and community practices into science lessons to demonstrate how scientific principles apply to their everyday lives (TC).

Rural communities often have diverse cultural backgrounds, including various traditions, languages, and ways of life. Culturally relevant curriculum and instruction recognise and value this diversity, affirming learners' identities and fostering a sense of belonging in the classroom.

Discussion

Our study explores the challenges learners and teachers face in teaching and learning physical sciences in rural schools, specifically in the Joe Gqabi district of South Africa. The discourse is around the interplay between the dilemma of physical sciences teachers and learners and the constructivism and self-study theories and the relevant literature in a rural context.

Constructivism theory posits that teachers have a vital role in assisting the learning process by establishing a supportive learning environment for learning to take place. Constructivism further highlights the active role of learners in constructing their understanding of the world through experiences and reflection (Sümer, 2021). In rural schools, where students may have diverse linguistic and cultural backgrounds, constructivism provides a framework that acknowledges and values these differences, promoting inclusive physical science education. By integrating constructivist approaches, teachers can create learning environments that cater to the specific needs of students from various backgrounds, ensuring equity in physical science education (Jalak & Nasri, 2019). On the other hand, the self-study theory examines teachers' actions and the context of those actions to develop a more consciously driven mode of professional activity as they reflect on their teaching strategies and identify areas for improvement.

The first finding shows that physical science teachers and learners face challenges in teaching and learning physical sciences in rural schools. Some of the challenges mentioned by both learners and teachers were the abstract nature of physical sciences concepts, which makes it difficult for learners to comprehend, mathematical complexity, lack of laboratory and science resources, language barrier, curriculum relevance, classroom environment, and community engagement. This result aligns with prior findings by Wang et al. (2020) and Humphrey-Darkeh et al. (2022) who indicated that rural schools often lack the essential resources and support systems necessary for effective physical science education, leading to decreased academic performance among students. This implies that the lack of resources contributes to lower physical science performance in rural schools compared to urban schools.

The second finding indicates that the challenges teachers and learners face in physical sciences in rural schools have affected their teaching and learning, such as limited hands-on learning opportunities, reduced learner engagement, unequal learning opportunities, limited extracurricular activities, influence on teacher instruction and low academic achievement among learners. This finding corroborates with previous studies, which indicated that learners, on the other hand, may encounter challenges to academic achievement due to factors such as poverty, lack of exposure to STEM fields, and restricted access to educational opportunities beyond the classroom (Zenda, 2017).

The last finding indicates that teachers have attempted to use various strategies to mitigate the challenges they face when teaching physical sciences in rural schools. Some of the strategies they listed were using low-cost resources, integrating practical demonstrations,

outdoor and field-based learning and extra classes, community collaboration and expert involvement, technology integration and culturally relevant curriculum and instruction. This finding aligns with Zinger et al. (2020) that hands-on and inquiry-based learning approaches effectively engage rural students and enhance their understanding of physical sciences. Providing students with opportunities to conduct experiments, explore real-world phenomena, and engage in problem-solving activities can foster curiosity and deepen conceptual understanding. The finding also concurs with Kormos and Wisdom (2021) that integrating technology into science education can overcome geographical barriers and provide rural students with access to high-quality instructional materials and resources. Virtual labs, online simulations, and video conferencing can supplement traditional classroom instruction and expose students to cutting-edge scientific concepts (Shambare & Simuja, 2021). In the context of rural schools, by encouraging hands-on learning experiences and critical thinking, constructivism can enhance the effectiveness of teaching science subjects in rural schools (Nawzad et al., 2018).

Conclusion

Teaching physical sciences in South African rural high schools presents complex challenges for both learners and teachers. The unique socio-economic circumstances, resource constraints, and inadequate infrastructure create a significant dilemma that hampers effective teaching and learning in these subjects. Despite these challenges, there are opportunities for improvement and strategies that can be implemented to enhance the quality of education in rural areas.

Therefore, to address the challenges identified, our study recommends:

- The government and relevant stakeholders prioritise investment in rural schools, ensuring they have adequate infrastructure, laboratories, textbooks, and other resources for effectively teaching physical sciences.
- Specialised training programs should be developed to equip teachers in rural areas with the necessary skills and knowledge to teach physical sciences effectively. Continuous professional development opportunities and mentorship programs can also provide ongoing support for teachers.
- Engage local communities in education by fostering partnerships between schools, parents, and community leaders. This involvement can help create a supportive environment for learning and provide additional resources and support for both learners and teachers.
- Teachers explore technology to supplement traditional teaching methods. Online resources, educational apps, and virtual laboratories can help bridge the gap in resource-constrained environments and make learning more interactive and engaging.
- Tailor the curriculum to the needs and interests of rural learners, incorporating real-life examples and contexts relevant to their experiences. This can increase student engagement and improve understanding of abstract scientific concepts. Ensure that teaching materials are available in languages spoken by rural communities. Teachers and schools can modify specific elements of the mandated curriculum to align more

effectively with rural learners' socio-economic conditions, cultural contexts, and practical requirements. By highlighting locally pertinent instances and initiatives, teachers can augment learner engagement and facilitate the connection between theoretical knowledge and daily experiences.

- Customise the curriculum by providing practical education as an alternate option for Grade 12 learners who may not like to engage in only academic disciplines such as physical sciences. Vocational topics may encompass agricultural sciences, mechanics, or environmental studies, which are more congruent with rural regions' local economy and career prospects.
- Customising the curriculum in this manner helps guarantee that rural students obtain an education that is both pertinent and powerful, equipping them for prosperous futures within their local environments.
- Introducing bilingual education programs and language support initiatives can help overcome language barriers and improve learning outcomes.

By implementing these recommendations, stakeholders can work towards overcoming the dilemmas faced by learners and teachers in rural South African high schools, ultimately improving the quality of education and empowering students to succeed in physical sciences.

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Appendix A: Teachers interview questions

Tell me more about your teaching experience in terms of:
a. The number of years teaching physical sciences.
b. Which grades are you teaching currently?
c. Performance of learners for the past three years (pass percentage and symbol distribution.

Research question 1

1. What is your view in terms of the performance of learners in physical sciences at your school?
2. How do you perform in terms of producing good results for learners?
3. What do you think are the barriers to high performance in physical science at your school?
4. In your experience, how do students articulate their difficulties in grasping abstract concepts in physical sciences, and what specific topics seem to pose the greatest challenges?
5. Do your learners have adequate resources, such as textbooks and laboratory materials in learning physical science?
6. What are the obstacles students encounter in accessing additional academic support, such as tutoring or extracurricular activities, for physical sciences?
7. From your perspective, how do socio-economic factors, such as students' family backgrounds, influence their engagement and success in learning physical sciences in a rural setting?
8. How do challenges related to transportation and attendance affect students' continuity and progress in physical science education?
9. Do you perform experiments in your school?
10. Could you please enumerate the problems that you encounter when teaching theory as well as those that you encounter when you teach practical work in physical sciences?
11. What difficulties do students face in applying theoretical knowledge to practical

situations, especially when confronted with limited opportunities for hands-on experiences?
12. In your experience, how do students in settings with limited access to hands-on resources express their interest or disinterest in learning physical sciences?
13. How do language barriers or differences between teachers and students impact communication and comprehension in the learning of physical sciences?
14. How do cultural factors contribute to or hinder students' interest and motivation in pursuing studies in physical sciences in rural schools?

Research question 2

1. What are your goals in teaching physical sciences? Do you enjoy teaching physical sciences?
2. Do you regard your school as a well-resourced or poorly resourced school?
3. What challenges do teachers face in adapting the physical science curriculum to the specific needs and contexts of students in rural areas?
4. How does the shortage of qualified and experienced physical science teachers affect the overall learning experience for students in rural schools?
5. In what ways do infrastructure limitations, such as inadequate classrooms or lack of electricity, hinder effective teaching and learning of physical sciences in rural settings?
6. What difficulties do teachers encounter in fostering a hands-on and interactive approach to learning physical sciences when faced with limited access to practical resources?
7. What obstacles do teachers face in integrating technology into their physical science lessons, given potential limitations in rural areas?
8. How do language and cultural differences between teachers and students affect communication and understanding in the context of teaching physical sciences in rural schools?
9. What challenges do teachers encounter in establishing and maintaining a supportive learning environment for physical sciences, considering the often small and multi-grade classrooms in rural settings?

Research question 3

1. How do resource limitations in rural schools impact the quality of laboratory experiences and hands-on activities in physical science classrooms?
2. How does the shortage of qualified science teachers in your school affect the overall academic performance of students in physical sciences?
3. How does the lack of professional development opportunities for science teachers affect their ability to incorporate innovative teaching methods in physical science classes?
4. How do infrastructure challenges, such as inadequate classrooms and outdated facilities, impact the overall learning environment for physical sciences in rural schools?
5. How do cultural factors in rural communities influence the integration of indigenous knowledge and practices into the teaching of physical sciences?
6. How does the limited exposure to real-world applications of science affect students'

interest and motivation in pursuing further studies or careers in physical sciences in rural areas?

Research question 4

1. What innovative teaching methods can be introduced to overcome resource limitations and enhance the effectiveness of physical science instruction in your school?
2. What strategies can be implemented to improve the accessibility and availability of up-to-date scientific resources, textbooks, and laboratory materials in rural classrooms?
3. How can technology be integrated into physical science education in rural schools to enhance learning experiences, despite potential infrastructure challenges?
4. What mentoring and support systems can be established to assist new and inexperienced physical science teachers in adapting to the rural teaching environment?
5. In your experience, what specific strategies or teaching approaches have proven effective in helping students overcome challenges associated with abstract concepts in physical sciences and enhance their understanding of the subject?
6. Shortage of qualified physical science teachers in rural schools?
7. What role can local government, non-governmental organisations, and educational authorities play in implementing and sustaining strategies to improve physical science education in your school?
8. How do you motivate your physical science learners to do better in the subject?
9. If you were asked by the district officials to suggest ways in which the quality of results can be improved, what suggestions would you put forward?

Appendix B: Learners interview questions

Research question 1

1. After completing Matric, what are you going to study at the tertiary institution?
2. What are your goals in physical sciences? Where do you see yourself in five years?
3. How do you rate your performance in physical sciences?
4. Do you enjoy learning physical sciences? If the answer is no, state the reason/s why?
5. Is there anything that can make it difficult for you to pass (achieve your goal) physical sciences? What are these?
6. Do you have any science laboratory in your school? If yes, do you often attend laboratory sessions for practical activities?
7. In your view, do you have access to physical sciences resources and learning materials?
8. In your view, do you have physical science teachers?
9. Do you feel adequately supported in your studies?
10. How does the language of teaching and learning affect your comprehension and engagement with physical science content?
11. Do you engage in any extracurricular activities in the school?

Research question 2

1. How does the limited availability of laboratories and practical resources impact your ability to understand and apply physical science concepts in a hands-on manner?
2. In your view, in what ways does the shortage of qualified science teachers affect your learning experience
3. How does the economic situation of your community impact your access to essential learning resources, such as textbooks, and does it affect your commitment to studying physical sciences?
4. How does the language of teaching and learning affect your comprehension and engagement with physical science content?
5. How do you think limited extracurricular activities and trips affect your practical exposure and understanding of real-world applications of physical sciences
6. In which ways do you think you will be able to learn better to improve on your performance?
7. What do you think should be done to improve learner performance in physical sciences?
8. What kind of support do you receive from your parents regarding your schoolwork?
9. What kind of support do you want from your teachers and school staff to enable you perform well in physical sciences?

Thank you for your participation.

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