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Exploring pedagogical practices and learner engagement in grades 10 and 11 physical sciences classrooms

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ABSTRACT

To address the persistent challenges faced by South African learners' underperformance in Mathematics and Physical Sciences, the study investigated the impact of interactive classroom practices on academic engagement. Using simple random sampling, data were collected from 123 grades 10 and 11 physical sciences learners who participated in a correlational study. The learners rated how often their teachers use investigative methods, group discussion, educational resources, and indirect teaching styles to promote positive classroom environments. Analysis of the Spearman rho statistical output revealed a strong positive correlation between indirect teaching style and both the adoption of investigative methods and learners' engagement through group discussions. While a moderate link was found between classroom climate and indirect teaching, no statistically significant relationship existed between classroom climate and group discussion. These findings not only contribute to the field by highlighting the necessity of inquiry-based pedagogy and resource integration but also the importance of classroom practices that foster collaborative problem-solving to develop science process skills in learners. The study concludes that inquiry-based pedagogy, resource integration, and targeted teacher training are vital for fostering supportive learning environments. Potential variability associated with contextual factors such as learners' heterogeneity, availability of resources, and differences in teachers' implementation are some of the limitations of this study. Future longitudinal research is recommended to address contextual variables such as learner heterogeneity and resource availability.

Contribution/Originality: This study is one of the few that investigates the novel, context-specific correlation of inquiry-based practices, indirect teaching, classroom climate, and resources shaping learners' engagement in physical sciences classrooms. Effective implementation of inquiry-based pedagogy largely depends on teachers' development in teaching physical sciences.

1. INTRODUCTION

South African education is organized into three levels: higher education and training (HET), further education and training (FET), and general education and training (GET). Unlike in some global education systems, where physics and chemistry are taught as separate disciplines, the South African FET phase school system adopts an integrated approach, combining these two science disciplines into one subject officially known as Physical Sciences. It can also be argued that this approach streamlines the curriculum, potentially allowing for a more integrated and less compartmentalized view of the natural world. However, research conducted by the Trends in International

Mathematics and Science Study (TIMSS) in 2023 reveals that the average achievement score for South African learners was extremely low for both Grade 5 and 9 mathematics and science (Department of Basic Education, 2024). This stems from a lack of laboratory resources, which is often tied to school affluence, a language barrier owing to the language of teaching and learning, large class sizes, an abstract curriculum, and limited community involvement. Hence, South Africa's lower levels of innovation and income can be linked to its poor performance in science, technology, engineering, and mathematics (STEM) education subjects (National Advisory Council on Innovation, 2024). Naveed, Zhuparova, Ashfaq, and Rauf (2023) note that countries with higher average scores in reading, mathematics, and science as measured by the Programme for International Student Assessment (PISA) tend to have higher levels of innovation and income, as well as higher GDP per capita.

Furthermore, the 2021 National Senior Certificate (NSC) results have revealed that the learner performance in science shows a slight dip from 75.5% in 2020 to 74.7% in 2021, and an increase in mathematics pass rate from 65.8% in 2020 to 69% in 2021. These two reports indicate that the South African science community is shrinking owing to an inadequate number of people possessing critical, analytical, problem-solving and technical skills, which are necessary to uplift the country's economy. Zenda (2020) has found that a high number of learners in physical sciences classrooms can be a contributory factor towards the poor performance in the subject, which leads to several interconnected issues linked to the heavy load of marking, administrative issues, issues related to distraction and discipline affecting the flow of lesson delivery. Additionally, Ogegbo, Gaigher, and Salagaram (2019) have emphasized the importance of collaborative action-based research using lesson plans to enhance the teaching of physical sciences and argued that a lack of content knowledge obstructs meaningful engagement in physical sciences classes. The integration of physics and chemistry into a single physical sciences subject at the FET phase stands as a distinctive feature, reflecting a deliberate pedagogical choice to foster a holistic understanding of the physical world. The implementation of this teaching approach has both strengths and weaknesses, as it crucially shapes the fundamental knowledge and critical skills essential for the next generation of professionals, such as scientists, innovators, and engineers. However, this deliberate integration may also be a possible cause of poor performance in international assessments. This combination leads to specific pedagogical choices, resulting in targeted teaching strategies and models. It is well known that while teaching physics, the major focus is on mathematical modeling and a quantitative approach, whereas teaching chemistry involves more visualization and experimental observations. This discussion led the researchers to explore the following research questions.

1. What are the learning experiences of grades 10 and 11 physical sciences learners?
2. Is there a relationship between teacher application of investigative methods, indirect teaching style, classroom climate, group discussions and learning material use in grades 10 and 11 physical sciences?

2. LITERATURE REVIEW

Emphasis is being placed on the use of participatory and reflective teaching practices globally. The Physical Sciences Curriculum Guidelines, as outlined in the Curriculum and Assessment Policy Statement (CAPS), suggest that teachers adopt and implement teaching methods that promote inquiry, article-based teaching and learning by encouraging collaborative activities. Teachers are expected to utilize diverse learning resources that enhance learners' understanding and engagement (Department of Basic Education, 2011a). Enquiry and scientific experiments form the essentials of inquiry-based learning and promote a deeper level of understanding (Moeed, 2013). It is globally reported that learners' participation in open-ended investigations enhances their reasoning and problem-solving abilities. Despite this fact, current evidence (Talafian, Lundsgaard, Mahmood, Kuo, & Stelzer, 2025) suggests that many science teachers adopt a narrow approach to investigative methods and activities, prioritizing highly structured, fair tests in their classrooms over open-ended methods. This practice hinders deeper learning of scientific concepts. To resolve this, expanded pedagogical repertoire and a stronger grasp of scientific enquiry should become an essential part of targeted professional development. Utilizing these indirect, constructive pedagogies, including inquiry and problem-based learning, will help reposition teachers as facilitators guiding learners through the co-construction of knowledge (Hmelo-Silver, Duncan, & Chinn, 2007). A study conducted by Wang, Degol, Amemiya, Parr, and Guo (2020) reveals that a supportive classroom environment strengthens learners' self-efficacy and curiosity. Major curricula such as Cambridge Assessment International Education (2020) and CAPS promotes learner-centered methods such as peer work, group discussions, and questioning. These methods enable learners to explore errors and co-develop their understanding of science. Studies have shown that a combination of self-study and group discussion is more effective than lecturing (Lim, Yang, Song, & Park, 2025). Therefore, to foster an interactive learning environment, it is crucial to engage in group discussions. Furthermore, integrating resources such as digital apps, visual media and physical models into inquiry-based classrooms helps improve learner engagement and accommodate diverse learning styles by enhancing content mastery and retention (Akpen, Asaolu, Atobatele, Okagbue, & Sampson, 2024). A synergy between investigative learning strategies, a supportive classroom environment, indirect pedagogical methods, and flexible resources, therefore, assists in establishing an impactful framework for science education. However, South Africa has historically faced challenges in learner participation and performance in these crucial disciplines (Hanushek & Woessmann, 2010; Neamţu, 2023).

The number of grade learners enrolling for mathematics and physical sciences is declining in South Africa (Mhlolo, 2025; Moonstone Information Refinery, 2025). However, things are not gloomy, as 2021 results reveal that, compared to 2020, 2021 matriculants have improved their performance in mathematics and physical sciences by more than three percent. While these results are encouraging, a persistent gap in foundational STEM skills continues to constrain the country's economy, as indicated by the 2024 South African Science, Technology, and Innovation (STI) Indicator report. Therefore, there is clearly a need for more focused efforts and targeted research in improving physical sciences pedagogy to strengthen the educational foundation and to increase the number of learners ready for STEM subjects. While the global frameworks Cambridge Assessment International Education (2020) and Department of Basic Education (2011b) have mandated an inquiry-based approach to teach STEM subjects, a documented disconnect persists between classroom practice implementation and these mandates, where teachers still rely on rigid structured methods limiting learners' participation. This research addresses this gap by exploring the relationship between indirect teaching style, classroom climate, resources, and use of learning materials to improve the educational journey of grades 10 and 11 physical sciences learners.

3. METHODOLOGY

3.1. Theoretical Framework

This study is grounded in the constructivist theory. Constructivism posits that learners actively construct their own understanding and knowledge of the world through experiencing things and reflecting on those experiences. Instead of passively receiving information, individuals build mental models to make sense of new information, considering their existing knowledge and beliefs (McLeod, 2025). Cognitivist teaching methods aim to assist learners in assimilating new information into their existing knowledge, as well as enabling them to make the appropriate modifications to their intellectual framework to accommodate that information (Berkeley Graduate Division, 2026; Chand, 2023). When new information is integrated with existing knowledge and understanding, meaningful learning occurs. Therefore, teaching strategies should facilitate learner-centered classrooms where new knowledge is developed and integrated with preexisting information. This is attainable by involving learners in active problem-solving, collaboration, and hands-on activities, with the teacher serving as a facilitator (Piaget, 1953). While pedagogical experts may differentiate clearly between the theory of constructivism and reflective methods, it is important to recall that constructivism is related to learner-centered methods like inquiry-based learning and problem-based learning. Reflection remains central to elaboration and evaluation, which often lead to a deeper understanding of concepts. Hence, reflective learning acts as a strategy within constructivism (Le Cornu & Peters, 2005). Therefore, in the FET phase, reflective learning is considered a key element in physical sciences. Interactive teaching strategies encourage learners to actively construct knowledge (Department of Basic Education, 2011a). Experimentations and hands-on activities, accompanied by critical discussions, support collaborative efforts and enable learners to evaluate their comprehension and learning processes. The pedagogical methods advocated by CAPS are aligned with leading global curricula, such as those of the IB Diploma and Cambridge International A and AS levels, prioritizing active participation and inquiry-led activities that lead toward learner-centered strategies (Cambridge Assessment International Education, 2023; International Baccalaureate Organization, 2025). These methods promote the conceptual understanding and reasoning of learners in the physical sciences. Moreover, these strategies are designed to nurture reflective learners who can independently assess their learning, identify gaps and refine their future learning goals. Therefore, CAPS supports lifelong learning based on constructive principles and practices. These signify the importance of problem-solving skills and active learner participation in the classroom (Department of Basic Education, 2011a). Rooted in the constructive theories of Vygotsky (1978) and Piaget (1953), the role of teachers as facilitators is emphasized by enabling learners to collaboratively construct knowledge through reflection and interaction. Despite these theoretical reforms, the practical effectiveness of these measures is impacted by infrastructural inadequacy and poor teacher training. Teachers as facilitators play a crucial role in implementing constructive teaching and fostering a positive classroom environment by utilizing investigative methods-based activities that promote trust and safety, allowing learners to share ideas and take intellectual risks with confidence. These activities can also include group discussions and self-assessments that promote deeper understanding (Alonso-Tapia & Ruiz-Díaz, 2025; Bou Saad, Garcia, & Garcia, 2025; Çibukçiu, 2025), emphasizing that teacher-led activities lead to better student participation and deeper learning.

3.2. Research Design

This is a positivist study, employing a quantitative research approach that involved statistical data analysis. In educational research, quantitative research design is a robust strategy to collect measurable data, enabling researchers to investigate issues, examine hypotheses, detect patterns, uncover trends, and identify correlations between different variables (Creswell & Guetterman, 2025; Ormrod, 2023; Rajab, Pietersen, & Maree, 2025). When applied to the study of teaching practices in physical sciences, quantitative research design can effectively quantify the frequency of specific teacher behaviors and classroom elements. This enables an objective assessment and the potential to generalize findings to a broader learner population. Quantitative research measured the frequency with which physical science teachers engaged learners in investigative methods. Simple random sampling was done to select 149 grade 10 and 11 physical sciences learners who participated in the correlational study. The learners were randomly selected during extra physical science lessons offered at the university. The questionnaire was adopted from a Ph.D. study conducted by the second author. Its content was derived from chapters 2, 3, and 4 of the same Ph.D. study. A questionnaire with a four-point Likert scale strongly disagree (SD), disagree (D), agree (A), and strongly agree (SA) was constructed to elicit learners' responses and their teachers' use of investigative methods, indirect teaching style, classroom climate, group discussion, and learning material use. The distribution of 149 questionnaires was conducted after their parents provided informed consent for the researchers to administer the questionnaire. One hundred and twenty-three questionnaires were returned, representing an 82.6% return rate. Its Cronbach's alpha value was .89, suggesting moderately high internal consistency reliability for the questionnaire.

It is essential to note that an institutional policy on ethical clearance was in place for academic staff at the time of data collection. Informed consent was obtained from participants' parents or guardians, and all collected data were anonymized to protect participants' confidentiality. The data were collected by the first author while offering community service to the local school participants. These participants attended Saturday Science School at the university to improve their understanding and grasp of the science and mathematics curriculum. None of the participants were forced to answer the questionnaire; only those whose parents or guardians gave written permission for their children to participate in the study were allowed to answer the questionnaire without impacting their study time. The authors safely stored these questionnaires. The data collected were analyzed using IBM SPSS-27. Frequencies and percentages were used to analyze descriptive statistics. The non-parametric Spearman rho correlation coefficient measured the strength and direction of the monotonic relationship between two ranked variables.

4. RESULTS AND DISCUSSION

In Tables 1-5, descriptive statistics are presented, analyzed, and interpreted, while Table 6 provides correlation coefficients between each pair of variables listed.

Table 1. Use of investigative methods by the physical sciences teachers.

Questionnaire item		SD		D		A		SA	
		Count	%	Count	%	Count	%	Count	%
B1	My physical sciences teacher focuses on lessons that involve the exploration of important problems, which can be investigated at various levels of difficulty.	8	6.5	14	11.4	75	61.0	26	21.1
B4	My physical sciences teacher's lessons present some problems that develop my thinking skills.	8	6.5	24	19.5	55	44.7	36	29.3
B8	My physical sciences teacher consciously uses ideas I have raised in class.	19	15.4	23	18.7	65	52.8	16	13.0
B12	My physical sciences teacher encourages us to evaluate if our arguments are relevant to the ideas being discussed.	5	4.1	12	9.8	62	50.4	44	35.8
B14	My physical sciences teacher encourages us to investigate problems.	6	4.9	17	13.8	33	26.8	67	54.5
B16	Class discussions are conducted in an orderly fashion that emphasizes courtesy and a willingness to listen to each person's ideas.	8	6.5	22	17.9	65	52.8	28	22.8
B22	Our contributions in discussions are considered important in class.	5	4.1	11	8.9	70	56.9	37	30.1
B32	My physical sciences teacher helps me when I have trouble with the work.	6	4.9	15	12.2	55	44.7	47	38.2

An analysis of the data reveals that a significant majority (86.2%; item B12) of learners believe that their physical sciences teachers actively encourage them to assess the relevance of their arguments concerning the topic under discussion.

In contrast, a smaller proportion (65.8%, item B8) of learners feel that their teachers deliberately incorporate learner-generated ideas into classroom discourse. These findings support the qualitative studies conducted by Boateng (2024) and Ramaila, Mngomezulu, Ramnarain, and Dhurumraj (2025), which found that teachers incorporated learners' ideas into their lessons.

Table 2. Use of the indirect teaching style among physical sciences teachers.

Questionnaire Item		SD		D		A		SA	
		Count	%	Count	%	Count	%	Count	%
B7	When my physical sciences teacher talks, (s)he "questions, (s)he does not "tell."	29	23.6	47	38.2	35	28.5	12	9.8
B9	My physical sciences teacher redirects my questions in such a way that I am encouraged to arrive at my own answers	10	8.1	21	17.1	67	54.5	25	20.3
B10	My physical sciences teacher consciously bases his/her questions on my ideas in class.	16	13	43	35	50	40.7	14	11.4
B11	I am free to interchange my ideas with other learners in class.	5	4.1	16	13	68	55.3	34	27.6
B15	My physical sciences teacher emphasizes learning, rather than classroom discipline, when we are engaged in group work activities.	15	12.2	23	18.7	57	46.3	28	22.8
B18	My physical sciences teacher rewards free exchange of ideas in class.	15	12.2	21	17.1	46	37.4	41	33.3
B21	My physical sciences teacher avoids criticising ideas offered by us in class.	7	5.7	34	27.6	53	43.1	29	23.6
B26	My physical sciences teacher emphasizes that values are permissible areas for discussion.	6	4.9	27	22	80	65	10	8.1
B28	My physical sciences teacher plays a low-key role in directing my learning experience.	40	32.5	29	23.6	34	27.6	20	16.3
B30	My physical sciences teacher goes out of his / her way to help me.	27	22	34	27.6	52	42.3	10	8.1
B31	My physical sciences teacher considers my feelings in class.	9	7.3	13	10.6	59	48	42	34.1
B33	My physical sciences teacher talks with me.	19	15.4	30	24.4	46	37.4	28	22.8
B34	My physical sciences teacher is interested in my problems.	26	21.1	36	29.3	48	39	13	10.6
B35	My physical sciences teacher moves about the class to talk with me.	9	7.3	18	14.6	49	39.8	47	38.2

These findings suggest that 82.9% of learners (Item: B11) believe that their physical sciences teachers foster peer-to-peer exchange of ideas during class discussions. However, only 50.4% (Item B:30) believe that their teachers make a concerted effort to provide them with individual support. These findings are supported by studies conducted by Hofkens, Pianta, and Hamre (2023); Gaad (2022); and Ramírez, Guzmán-Lavín, Pulgar, and Candia (2025), who found that class discussions and scaffolding contribute to meaningful learning.

Table 3. Classroom climate in the physical sciences lessons.

Questionnaire Item		SD		D		A		SA	
		Count	%	Count	%	Count	%	Count	%
B5	When the lesson is in progress, I talk more than my physical sciences teacher.	42	34.1	51	41.5	21	17.1	9	7.3
B37	I make friends easily among learners in the physical sciences class.	1	0.8	7	5.7	46	37.4	69	56.1
B38	I know other learners in the physical sciences class.	1	0.8	6	4.9	49	39.8	67	54.5
B39	I am friendly to members of physical sciences class.	4	3.3	14	11.4	61	49.6	44	35.8
B40	Members of the physical sciences class are my friends.	4	3.3	7	5.7	64	52	48	39
B41	I work well with other class members.	3	2.4	11	8.9	72	58.5	37	30.1
B43	Learners in the physical sciences class like me.	7	5.7	14	11.4	40	32.5	62	50.4
B44	In the physical sciences class, I get help from other learners.	6	4.9	14	11.4	39	31.7	64	52

The findings indicate that 94.3% of learners (Item B:38) believe that their physical sciences teachers encourage them to build relationships with their classmates. Furthermore, all learners (Item B:41) (100%) report that their teachers create an environment that supports effective collaboration with peers. These results confirm the findings of Macalalag et al. (2024) and Ngema, James, and Sibanda (2024), who found that effective learner collaboration contributed to the development of productive learning environments.

Table 4. Group discussion in the Physical Sciences classroom.

Questionnaire Item		SD		D		A		SA	
		Count	%	Count	%	Count	%	Count	%
B6	I am free to discuss my ideas with other learners in class.	4	3.3	12	9.8	65	52.8	42	34.1
B17	I gain practice in scientific processes of acquiring knowledge.	7	5.7	13	10.6	81	65.9	22	17.9
B19	My physical sciences teacher allows us to move freely in the classroom while we are engaged in group work activities.	24	19.5	19	15.4	48	39	32	26
B24	All physical sciences topics are critically examined, not "taught as closed issues with a single "correct" solution.	9	7.3	33	26.8	58	47.2	23	18.7
B25	Use of unfounded, emotionally charged language is minimized in guided teaching and learning conversations.	8	6.5	24	19.5	78	63.4	13	10.6
B29	My physical sciences teacher takes a personal interest in me.	24	19.5	16	13	55	44.7	28	22.8
B42	I help other class members who are having trouble with their work.	4	3.3	15	12.2	67	54.5	37	30.1

The findings show that 83.8% of learners (Item: B17) believe that their physical sciences teachers encourage them to understand how scientific knowledge is developed. However, only 61% feel (Item B:19) that their teachers permit them to move freely around the classroom during group activities. These results confirm the findings of Balaoro (2024) and Wess, Priemer, and Parchmann (2023) who found that engaging learners in active learning activities enhanced learners' acquisition of scientific skills.

Table 5. Learning material used by the Physical Sciences teacher.

Questionnaire Item		SD		D		A		SA	
		Count	%	Count	%	Count	%	Count	%
B2	My physical sciences teacher uses learning materials that stimulate my interest.	9	7.3	20	16.3	61	49.6	33	26.3
B3	My physical sciences teacher makes many different learning resources available for my use.	2	1.6	30	24.4	60	48.8	31	25.2
B20	My physical sciences teacher encourages the testing of ideas in class.	6	4.9	9	7.3	64	52	44	35.8
B23	My physical sciences teacher evaluates us on growth in many aspects of the learning experience, rather than simply on the basis of facts required	12	9.8	20	16.3	70	56.9	21	17.1
B27	My physical sciences teacher allows for my maximum use of learning materials.	12	9.8	30	24.4	61	49.6	20	16.3

Analysis of the data in this table indicates that 87.8% (Item B:20) of learners perceive that physical sciences teachers encourage them to test their ideas in class. Almost two-thirds (65.9%) of learners (Item B:27) believe that their physical sciences teachers encourage the best use of learning material. This supports Balaoro (2024) study, which highlights the importance of active learning in developing scientific skills in learners. However, Osei-Himah and Adu-Gyamfi (2022) advocate that simply having resources is not enough; their impact lies with teachers possessing the necessary skills and training to deploy learning material usage effectively. Additionally, Mavhunga (2024) emphasizes that teachers' attitudes towards learner-centered methodologies influence learners' engagement in the classroom.

Table 6. Relationship between investigative methods, indirect teaching style, classroom climate, group discussion, and learning material use.

Variables	Investigative methods	Indirect teaching style	Classroom climate	Group discussion	Learning material use
Investigative methods	-	0.56**	0.30**	0.35**	0.46**
Indirect teaching style	0.56**	-	0.28**	0.57**	0.42**
Classroom climate	0.30**	0.28**	-	00.13	00.16
Group discussion	0.35**	0.57**	0.13	-	0.30**
Learning material use	0.46**	0.42**	0.16	0.30**	-

Note: **. Correlation is significant at the 0.01 level (2-tailed).

Analysis of data in Table 6 reveals that there is a strong positive correlation between investigative teaching methods and use of indirect instructional styles ($r=0.56$, $n=123$, $p<0.001$). This confirms the findings of Twizeyimana, Musinguzi, and Niyonzima (2014) that indirect teaching styles promote teacher adoption of inquiry-based education methods. Furthermore, a strong positive correlation exists between group discussion and indirect teaching style ($r = 0.57$, $n = 123$, $p < 0.00$). This confirms the findings of Alhassan and Owusu (2023) study. However, further analysis of the data reveals that there is a weak positive correlation between classroom climate and indirect teaching style ($r=0.28$, $n=123$, $p<0.001$). Moreover, there is a weak positive correlation between group discussion and classroom climate ($r=0.13$, $n=123$, $p>0.05$). These findings confirm Wang and Degol (2016) argument that environmental perception or classroom climate may not have any impact on the dynamics of collaborative work.

Physical science teachers promoting experimentation and idea verification were acknowledged by 87.8% learners, indicating endorsement of inquiry-based pedagogy. Laid and Adlaon (2025) have established that learner-centred teaching strategies reinforce engagement and assist with conceptual mastery. A commendable 65.9% of learners reported having open access to learning materials, yet limitations linked to hands-on resources such as lab equipment and related materials exist. Comprehensive and diverse learning material access is key for formative assessment and custom-made instructions, as supported by AlAli and Al-Barakat (2025). Therefore, as much as experimentation should be promoted, critical access to resources remains vital to promote active science learning. The key findings of this research underscore the importance of multiple interconnected reforms in promoting physical sciences teaching and learning. Most critical among these is fair access to resources, which facilitates experiential learning, fostering a more inclusive learning environment (Singleton et al., 2024). Closing the resource gap will assist in promoting hands-on experiential learning, enabling learners to understand complex concepts through interactive and collaborative classrooms. As noted by Alhassan and Owusu (2023), collaborative learning acts as a crucial bridge connecting practical applications with theoretical knowledge, which not only motivates development and social engagement but also fosters learners' autonomy, ultimately helping them to improve their academic results. Studies (Cole, Schroeder, Bataineh, & Al-Bataineh, 2021; Prival, Vélez, Vargas, & Cheung, 2017) have shown that adoption of flexible seating arrangements and dynamic classroom design can boost engagement and peer interaction and strengthen the effectiveness of group activities. To sustain reforms in science education, pedagogical training that focuses on inquiry and a learner-centred approach is vital (Sağlam & Şahin, 2017).

However, unequipped laboratories and inadequate infrastructure hamper these reforms, especially in under-resourced schools, preventing a flexible classroom environment. Policy coordination, mobile science kits, flexible spaces, and targeted funding initiatives can help mitigate these challenges effectively (Constantinou, 2019; Institute of Education Sciences, 2024). Transitioning to a learner-centred approach is not easy due to teachers' resistance, inconsistent training, and structural constraints. Overcrowded and diverse classrooms cause management difficulties and limit instructional effectiveness (Gholam, 2019; Hulac & Briesch, 2017). Comprehensive strategies are required to address these challenges, including curriculum redesign, policy alignment, and investment in infrastructure. In rural South Africa, improving funding and resource allocation remains a key factor in enhancing science education (Soyikwa & Boateng, 2024).

To advance science education reforms, future empirical investigations are essential to examine the effectiveness of these proposed interventions through longitudinal studies that encompass diverse educational contexts. Given the short duration of this study, it limits its ability to account for diverse contexts characterized by teachers' variability, resource limitations, and learners' heterogeneity. Future research should broaden sampling frames to evaluate the scalability and sustainability of learner-centered pedagogies (Deehan, MacDonald, & Morris, 2024; Tindan & Anaba, 2024). Teacher training should be embedded into these policy frameworks to ensure systemic adoption with effective classroom management skills based on inquiry-based classrooms (Iweama, 2024). Combining classroom data with policy analysis could inform targeted interventions, ensuring that reforms are context-sensitive and impactful (Sirianansopa, 2024).

5. CONCLUSION

There is evidence that teachers' pedagogical practices engage learners in productive science classrooms. This implies that teachers adhere to the prescripts of the physical sciences CAPS document, where teachers incorporate learners' generated ideas into discourse to improve critical thinking. However, the integration and validation of learners' ideas are less consistently implemented. It is further advocated that a high percentage of teachers are implementing group discussions to promote collaborative learning; yet, a gap exists where teachers have provided individual support, suggesting that specific learners who need to grasp the subject knowledge are overlooked. This highlights the need for pedagogical improvement, as scaffolding is comprehensive, addressing both collaborative and personalized learning needs. Designing group activities in such a way that interactive movements within the classroom are permitted will assist in improving collaborative learning, as these are hindered by classroom management practices. To address the successful deployment and effective integration of resources, professional training to utilize resources strategically is necessary and should be incorporated into policies. Teachers' training should be aligned to improve people's skills (social and emotional), making learners feel safer and more comfortable to improve teamwork results. Teachers are adopting learner-centred pedagogy, yet an implementation gap still exists where teachers struggle to make the best possible use of existing material and equipment to run hands-on activities long after achieving democracy in South Africa, indicating systematic issues inherited from the past.

Future empirical research is needed to explore the impact of these interventions and guide reforms that promote innovative science education in a productive learning environment. This was a short-duration study, and outcomes may vary based on the context-specific environment, learner diversity, resource limitations, and implementation variability associated with teachers. Therefore, future longitudinal studies, including a larger and broader population, are required and planned by the authors.

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REFERENCES

Akpen, C. N., Asaolu, S., Atobatele, S., Okagbue, H., & Sampson, S. (2024). Impact of online learning on student's performance and engagement: A systematic review. *Discover Education*, *3*(1), 205. https://doi.org/10.1007/s44217-024-00253-0

AlAli, R. M., & Al-Barakat, A. A. (2025). Enhancing young children's science learning through science teachers' formative assessment practices. *Frontiers in Education*, *10*, 1503088. https://doi.org/10.3389/feduc.2025.1503088

Alhassan, A. M., & Owusu, K. A. (2023). Exploring the impact of indirect teaching strategies on collaborative learning in senior high school science classes. *African Journal of Educational Studies in Mathematics and Sciences*, *19*(1), 88–101.

Alonso-Tapia, J., & Ruiz-Díaz, M. (2025). Classroom climate: Empirical validation and educational implications of a conceptual model: A multilevel study. *Psicología Educativa*, *31*(2), 129-139. https://doi.org/10.5093/psed2025a19

Balaoro, M. J. B. (2024). Enhancing scientific skills among students through engaging in active learning activities. *United International Journal for Research & Technology*, *5*(7), 242-251.

Berkeley Graduate Division. (2026). *Cognitivism in education*. Berkeley: University of California.

Boateng, S. (2024). Physical sciences teachers' perspectives on implementing learning style-based instructional strategies in science classrooms: Challenges and opportunities. *Journal of Pedagogical Research*, *8*(4), 202-219. https://doi.org/10.33902/JPR.202426770

Bou Saad, R., Garcia, A. L., & Garcia, J. M. C. (2025). Mapping constructivist active learning for STEM: Toward sustainable education. *Sustainability*, *17*(13), 6225. https://doi.org/10.3390/su17136225

Cambridge Assessment International Education. (2020). *Cambridge IGCSE and A-level science syllabuses*. Cambridge: Cambridge University Press.

Cambridge Assessment International Education. (2023). *Cambridge international as & a level syllabuses*. Cambridge: Cambridge University Press.

Chand, S. P. (2023). Constructivism in education: Exploring the contributions of Piaget, Vygotsky, and Bruner. *International Journal of Science and Research*, *12*(7), 274-278. https://doi.org/10.21275/SR23630021800

Çibukçiu, B. (2025). The relationship between constructivist approach and inclusive education in primary school. *Frontiers in Education*, *10*, 1600711. https://doi.org/10.3389/feduc.2025.1600711

Cole, K., Schroeder, K., Bataineh, M., & Al-Bataineh, A. (2021). Flexible seating impact on classroom environment. *Turkish Online Journal of Educational Technology*, *20*(2), 62-74.

Constantinou, C. (2019). *Professional development for inquiry-based science teaching and learning*. United States: Springer.

Creswell, J. W., & Guetterman, T. C. (2025). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. United States: Pearson.

Deehan, J., MacDonald, A., & Morris, C. (2024). A scoping review of interventions in primary science education. *Studies in Science Education, 60*(1), 1-43. https://doi.org/10.1080/03057267.2022.2154997

Department of Basic Education. (2011a). *Curriculum and assessment policy statement (CAPS): General overview*. South Africa: Government Printer.

Department of Basic Education. (2011b). *Curriculum and assessment policy statement grades 10-12: Physical sciences*. South Africa: Government Printer.

Department of Basic Education. (2024). *South African 2023 trends in international mathematics and science study (TIMSS) highlights report*. South Africa: Department of Basic Education.

Gaad, A. L. V. (2022). The effects of online collaborative learning (OCL) on student achievement and engagement. *IAFOR Journal of Education, 10*(3), 31-49. https://doi.org/10.22492/ije.10.3.02

Gholam, A. P. (2019). Inquiry-based learning: Student teachers' challenges and perceptions. *Journal of Inquiry and Action in Education, 10*(2), 112-133.

Hanushek, E. A., & Woessmann, L. (2010). *The high cost of low educational performance: The long-run impact of improving PISA outcomes*. Paris, France: OECD Publishing.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist, 42*(2), 99-107. https://doi.org/10.1080/00461520701263368

Hofkens, T., Pianta, R. C., & Hamre, B. (2023). Teacher-student interactions: Theory, measurement, and evidence for universal properties that support students' learning across countries and cultures. In R. Maulana, M. Helms-Lorenz & R. M. Klassen (Eds.), Effective teaching around the world: Theoretical, empirical, methodological and practical insights. In (pp. 399–422). Cham, Switzerland: Springer.

Hulac, D. M., & Briesch, A. M. (2017). *Evidence-based strategies for effective classroom management*. United States: The Guilford Press.

Institute of Education Sciences. (2024). *Framework for equitable opportunities to learn in STEM*. United States: IES.

International Baccalaureate Organization. (2025). *The IB learner profile*. Switzerland: International Baccalaureate Organization.

Iweama, C. N. (2024). Inquiry-based Instruction (IBI) as a Teaching Strategy. In E. O. Adu, B. I. Omodan, C. T. Tsotetsi, & B. Damoah (Eds.), Pedagogical strategies for 21st-century classrooms. In (pp. 23-29). Nigeria: ERRCD Forum.

Laid, S. M. T., & Adlaon, M. S. (2025). A systematic review of innovative teaching strategies in science: Exploring hands-on learning, technology integration, and student-centered approaches. *Acta Pedagogia Asiana, 4*(2), 101-114. https://doi.org/10.53623/apga.v4i2.645

Le Cornu, R., & Peters, J. (2005). Towards constructivist classrooms: The role of the reflective teacher. *Journal of Educational Enquiry, 6*(1), 50–64.

Lim, J., Yang, J. W., Song, M. H., & Park, J. (2025). Self-study and discussion promote students' science learning. *Science & Education, 34*(4), 2459-2477. https://doi.org/10.1007/s11191-024-00562-8

Macalalag, J. A. Z., Kaufmann, A., Van Meter, B., Ricketts, A., Liao, E., & Ialacci, G. (2024). Socioscientific issues: Promoting science teachers' pedagogy on social justice. *Disciplinary and Interdisciplinary Science Education Research, 6*(1), 28. https://doi.org/10.1186/s43031-024-00118-4

Mavhunga, E. (2024). The influence of science teachers' beliefs and practices on student engagement. In R. Maulana, M. Helms-Lorenz & R. M. Klassen (Eds.), Science Education in Context. In (pp. 455–472). Germany: Springer.

McLeod, S. (2025). *Constructivism learning theory & philosophy of education*. United Kingdom: SimplyPsychology.

Mhlolo, M. K. (2025). Excellence for some before equity for all: Re-examining the national strategy for mathematics education through the capability approach theory. *South African Journal of Education, 45*(2), 1-11. https://doi.org/10.15700/saje.v45n2a2423

Moeed, A. (2013). Science investigation that best supports student learning: Teachers' understanding of science investigation. *International Journal of Environmental and Science Education, 8*(4), 537-559.

Moonstone Information Refinery. (2025). *Concern over decline in matric candidates writing STEM gateway subjects*. South Africa: Moonstone Information Refinery.

National Advisory Council on Innovation. (2024). *South Africa science, technology and innovation indicators report 2024*. Pretoria, South Africa: National Advisory Council on Innovation.

Naveed, A., Zhuparova, A., Ashfaq, M., & Rauf, A. (2023). The effect of average scores in reading, mathematics and science on innovation and income: A quantitative analysis for a group of countries. *Heliyon, 9*(9), e19213. https://doi.org/10.1016/j.heliyon.2023.e19213

Neamţu, D.-M. (2023). Theories and models on the relationship between education and economic development. In Education and Economic Development (pp. 49–70). Cham, Switzerland: Palgrave Macmillan. https://doi.org/10.1007/978-3-031-20382-4_3

Ngema, S., James, A., & Sibanda, D. (2024). The role of novice physical sciences teachers' goals in the implementation of inquiry-based instruction. *Cogent Education, 11*(1), 2429364. https://doi.org/10.1080/2331186X.2024.2429364

Ogegbo, A. A., Gaigher, E., & Salagaram, T. (2019). Benefits and challenges of lesson study: A case of teaching Physical Sciences in South Africa. *South African Journal of Education, 39*(1), 1-9. https://doi.org/10.15700/saje.v39n1a1680

Ormrod, J. E. (2023). *Practical research: Design and process* (13th ed.). Hoboken, NJ: Pearson.

Osei-Himah, V., & Adu-Gyamfi, K. (2022). Teachers' perspective of effective use of teaching and learning materials in basic school integrated science lessons. *Asian Journal of University Education, 18*(1), 256–270.

Piaget, J. (1953). *The origin of intelligence in the child*. United Kingdom: Routledge & Kegan Paul.

Prival, L., Vélez, D., Vargas, C., & Cheung, C. (2017). *Equity and access for all students*. Retrieved from https://classroomscience.org/articles/ngss/ngss-early-implementers/equity-and-access-all-students

Rajab, P., Pietersen, J., & Maree, K. (2025). Statistical analysis I: Descriptive statistics. In K. Maree (Ed.), First steps in research. In (pp. 257-273). Pretoria, South Africa: Van Schaik.

Ramaila, S., Mngomezulu, H., Ramnarain, U., & Dhurumraj, T. (2025). Teachers' perspectives on formative assessment in physical sciences education. *African Perspectives of Research in Teaching and Learning, 9*(1), 28-45.

Ramírez, D., Guzmán-Lavín, E. J., Pulgar, J., & Candia, C. (2025). Self-select groups increase stability but reduce collaboration in high school physics. *Physical Review Physics Education Research, 21*(1), 010157. https://doi.org/10.1103/PhysRevPhysEducRes.21.010157

Sağlam, M. K., & Şahin, M. (2017). Inquiry-based professional development practices for science teachers. *Journal of Turkish Science Education, 14*(4), 66-76.

Singleton, C., Deverel-Rico, C., Penuel, W. R., Krumm, A. E., Allen, A.-R., & Pazera, C. (2024). The role of equitable classroom cultures for supporting interest in science. *Journal of Research in Science Teaching, 61*(5), 998-1031. https://doi.org/10.1002/tea.21936

Sirianansopa, K. (2024). Evaluating students' learning achievements using the formative assessment technique: A retrospective study. *BMC Medical Education, 24*(1), 1373. https://doi.org/10.1186/s12909-024-06347-5

Soyikwa, L., & Boateng, S. (2024). Teaching physical sciences in South African rural high schools: Learner and teacher views about the challenges. *Issues in Educational Research, 34*(4), 1573-1595.

Talafian, H., Lundsgaard, M., Mahmood, M. S., Kuo, E., & Stelzer, T. J. (2025). Teachers' experiences with taking an open-ended approach in teaching labs in high school physics classes. *Physical Review Physics Education Research, 21*(1), 010140. https://doi.org/10.1103/PhysRevPhysEducRes.21.010140

Tindan, T. N., & Anaba, C. A. (2024). Scientific hands-on activities and its impact on academic success of students: A systematic literature review. *IOSR Journal of Research & Method in Education, 14*(6), 39-47.

Twizeyimana, J. D., Musinguzi, D., & Niyonzima, E. (2014). Investigative teaching and learner-centered strategies in science classrooms: A case study of Rwandan secondary schools. *International Journal of Science Education, 46*(2), 145–162.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes.* United States: Harvard University Press.

Wang, M.-T., & Degol, J. L. (2016). School climate: A review of the construct, measurement, and impact on student outcomes. *Educational Psychology Review, 28*(2), 315-352. https://doi.org/10.1007/s10648-015-9319-1

Wang, M.-T., Degol, J. L., Amemiya, J., Parr, A., & Guo, J. (2020). Classroom climate and children's academic and psychological wellbeing: A systematic review and meta-analysis. *Developmental Review, 57*, 100912. https://doi.org/10.1016/j.dr.2020.100912

Wess, R., Priemer, B., & Parchmann, I. (2023). Professional development programs to improve science teachers' skills in the facilitation of argumentation in science classroom—a systematic review. *Disciplinary and Interdisciplinary Science Education Research, 5*(1), 9. https://doi.org/10.1186/s43031-023-00076-3

Zenda, R. (2020). Impact of the learner-educator ratio policy on learner academic achievement in rural secondary schools: A South African case study. *Africa Education Review, 17*(3), 37-51. https://doi.org/10.1080/18146627.2019.1588748