The power of inquiry-based chemical change lesson in under-resourced classrooms: Perspectives of grade 10 learners

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This qualitative study delves into the learner experience of inquiry-based lessons, uncovering the perceptions and insights of learners engaged in this pedagogical approach. Through focus group interviews, we gathered rich data that reveals a transformative learning environment characterized by active engagement, collaborative discourse, and autonomy. Learners embraced the opportunity to explore concepts independently, seeking clarification from peers and cultivating a deeper understanding of the subject matter. Notably, despite feeling unsupported by their teachers, learners perceived the limited teacher involvement as a liberating force, fostering independence and encouraging more extensive reading and peer discussion. Our findings resonate with existing research, underscoring the efficacy of inquiry-based learning in promoting learner-centeredness, critical thinking, and conceptual understanding. The study's outcomes have significant implications for science education, highlighting the need for a paradigmatic shift from traditional teacher-centric approaches to learner-centered inquiry-based methods that empower students to take ownership of their learning.

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inquiry-based lesson, perspectives, chemical change.

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1 Introduction

The struggles learners face in grasping the concept of chemical change can be attributed to the prevalent teaching approaches employed in Physical Sciences classrooms. Despite the established benefits of inquiry-based teaching and learning in Science, research suggests that most teachers still rely on traditional lecture methods, characterized by teacher-centric instruction and limited learner engagement (Mamombe et al., 2020; Penn et al., 2021). This disconnect between recommended and actual teaching practices highlights the need to investigate learners' perceptions of inquiry teaching, particularly in chemical change, where inquiry-based approaches are emphasized in the curriculum but often overlooked in practice (Penn et al., 2021). By exploring learners' perspectives, we can better understand the barriers and facilitators to effective teaching and learning in Science, ultimately informing strategies to enhance learner understanding and engagement.

Recent studies have investigated the complex interplay between teachers' beliefs, instructional approaches, and student outcomes in science education. For instance, Li et al. (2024) explored the relationship between science teachers' beliefs about inquiry-based teaching and their students' development of science process skills. Meanwhile, Safkolam, Madahae, and Saleah (2024) examined the impact of inquiry-based learning activities on science student teachers' understanding of the nature of science. Furthermore, Achurra, Uskola, and Zamalloa (2024) investigated pre-service teachers' perceptions of their preparedness to implement science as inquiry in their future teaching practices. These studies contribute to a deeper understanding of the multifaceted factors influencing science education. Gyllenpalm et al. (2021) conducted a seminal study examining students' understanding of scientific inquiry and the potential impact of school science on this knowledge. Their findings revealed a concerning trend, wherein many students in both grade levels demonstrated a lack of informed understanding of key aspects of scientific inquiry. In a related investigation, Kersting et al. (2023) developed and employed a rigorous observation manual to systematically analyze video data of instructional practices in 20 Norwegian science classrooms across primary and lower-secondary school levels. Notably, their findings suggest that inquiry-based teaching approaches not only afford students greater autonomy in decision-making but also enhance the quality of student participation in the classroom, thereby underscoring the importance of pedagogical strategies that foster student agency and engagement in science learning. Lu and So (2023) explored the intersection between English Medium Instruction (EMI) and scientific inquiry, scrutinizing science teachers' cognitive and affective responses to implementing inquiry-based science activities in EMI classrooms. Their study revealed that teachers encountered a unique set of challenges in EMI contexts, including the tension between passive language acquisition and the reciprocal learning of scientific inquiry and language, as well as the pedagogical dilemma posed by the incongruity between inquiry-based science teaching and the linguistic demands of EMI. These findings underscore the complexities inherent in integrating scientific inquiry and language learning in EMI settings. A recent South African study by Siphukhanyo and Olawale

(2024) investigated the experiences of life sciences teachers and learners on the usage of enquiry-based learning in enhancing learners' academic performance.

Notwithstanding the abundance of research on inquiry-based teaching, there is a significant scarcity of studies investigating the perceptions of Grade 10 chemical change learners in South Africa. Inquiry-based studies have primarily employed quantitative approaches to examine the impact or effect of inquiry-based activities. There is a need for qualitative research that explores the perceptions and experiences of Grade 10 chemical change learners in South Africa to gain a deeper understanding of their needs and preferences in the context of inquiry-based teaching. Studies have consistently shown that inquiry-based teaching and learning approaches improve learners' conceptual understanding and performance in Physical Sciences (Mamombe et al., 2020; Penn et al., 2021). Therefore, the research question for this study is: What are the learners' perspectives on the effectiveness of inquiry-based teaching in enhancing their understanding of the concept of chemical change?

2 Conceptual Framework and Literature Review

The concept of inquiry-based learning has its roots in the seminal work of Gagne (1963), who advocated for a science education approach centered on three core objectives: cultivating attitudes, methods, and understanding of inquiry. According to Gagne, learners should develop the capacity to investigate scientific phenomena in a manner akin to professional scientists. This entails acquiring essential skills, including, observing and inferring, predicting and classifying, interpreting data and hypothesizing, and experimenting. Gagne (1963) emphasized that mastering these capabilities is crucial for learners to comprehend scientific concepts genuinely. Building on Gagne's (1963) ideas, Schwab (1966) argues that science education should replicate the scientific process. To achieve this, Schwab stresses the importance of incorporating science laboratories into teaching practices, thereby promoting inquiry-based learning. This approach becomes a recurring theme in Gagne's (1963) works. The study centers around the concept of inquiry as a guiding conceptual framework. Research suggests that science teachers often hesitate to implement inquiry-based strategies due to perceived difficulties in execution (Nicol et al., 2020). Teachers (Ong et al., 2021) tend to view inquiry-based approaches as ambiguous and poorly defined. The concept of inquiry has been defined and redefined by various researchers, often aligned with the specific objectives of their studies. Literature has generally conceptualized inquiry as a learner-centered approach, where learners engage in exploration, questioning, discovery, and experimentation to develop a deeper understanding of a topic. Penn et al. (2021) define inquiry as an active learning approach where students tackle challenging problems, gather evidence, and develop an understanding of core concepts and learning strategies. Kazeni and Mkhwanazi (2021) describe inquiry as a teaching method that enables students to investigate, build knowledge, and understand the world around them while developing essential scientific skills such as questioning, data gathering, and evidence-based conclusion drawing. Notably, the 1996 National Sciences Education Standards (NSES) provide a foundational definition of inquiry, widely referenced in the research community, which encompasses a multifaceted process involving observation, questioning, investigation, critical thinking, and communication (National Research Council, 2000). This definition has served as a basis for subsequent interpretations and adaptations of the concept of inquiry.

Upon closer examination, the various definitions of inquiry reveal a common thread – a focus on learner activities. This convergence aligns with Jerrim, Oliver, and Sims' (2019) assertion that inquiry aims to empower learners with knowledge through engagement in scientific activities rather than merely receiving information from teachers. In an inquiry-oriented science classroom, learners take center stage, conducting investigations, performing experiments, asking questions, and making observations to solve problems, thereby enhancing their critical thinking skills and deepening their understanding of science concepts (Gyampon et al., 2020). Susilawati et al. (2020) echo this sentiment, highlighting the need for learner-centeredness in inquiry-based science education, where learners independently seek knowledge and utilize their thoughts and experiences to address problems in the classroom and beyond. The National Sciences Education Standards (NSES) distil the essence of inquiry into learner activities, including engagement with scientifically based questions, evidence-based explanations, formulation of explanations, connection to scientific knowledge, and presentation and support of explanations (National Research Council, 2000). These activities encapsulate the learner-centered nature of inquiry, emphasizing the agency and autonomy of learners in the learning process.

The reviewed literature reveals a paradigm shift in the roles of teachers in inquiry-based learning, diverging from traditional classroom dynamics. The definitions of inquiry emphasize the learner's role, signaling a departure from rote teaching methods. There are generally critiques of traditional methods for prioritizing teacher-centric approaches over learner engagement. In contrast, inquiry-based learning repositions the teacher as a facilitator, challenging learners to think critically, analyze, and experiment. This facilitator role aims to empower learners to construct their knowledge, adopting a scientist-like mindset. Effective facilitation involves scaffolding, motivation, and judicious intervention to maintain learner interest and autonomy.

Liu and Wang (2022) investigated the nexus between inquiry-based learning and science self-efficacy, revealing a statistically significant positive correlation between the two variables. Notably, their findings suggest that science interest plays a mediating role, partially explaining the relationship between inquiry-based learning and science self-efficacy. This study provides empirical evidence that inquiry-based learning not only enhances science self-efficacy but also fosters science interest, which in turn reinforces self-efficacy beliefs. The findings have implications for the design of science learning environments that aim to promote students' self-efficacy and interest in science.

Jerrim et al. (2019) identify two crucial dimensions that underpin inquiry-based learning: the range of classroom activities engaging learners and the degree of teacher involvement. This framework gives rise to four distinct inquiry types, which teachers can deliberately choose from to align with their lesson's specific aims and objectives (Banchi & Bell, 2008). By acknowledging and adapting to these variations, educators can harness the full potential of inquiry-based learning, fostering a dynamic and effective science education environment. Therefore, confirmatory inquiry, structured inquiry, guided inquiry and open inquiry are critical, as discussed in the following paragraph.

Firstly, confirmation inquiry, the most basic form of inquiry, serves as an introductory approach to acquaint learners with investigation skills and the inquiry method, particularly suited for reinforcing previously taught topics (Banchi & Bell, 2008). Toma (2022) characterizes this type of inquiry as logically positivist, as it relies heavily on teacher demonstration and provision of information. However, Jerrim et al. (2019) critique confirmation inquiry for lacking authentic inquiry elements, as learners are provided with predetermined research questions, objectives, and outcomes, limiting their agency and critical thinking. The primary concern lies in the excessive teacher involvement and limited learner engagement. In confirmation inquiry, the teacher formulates research questions, guides the investigation process, and provides the conclusions, leaving learners with minimal challenging activities (Toma, 2022). While this approach contradicts the fundamental principles of inquiry (Jerrim et al., 2019), Toma (2022) argues that confirmation inquiry remains a valuable improvement over traditional rote teaching methods despite its limitations.

Secondly, confirmation and structured inquiry represent the foundational levels of inquiry-based learning, characterized by a more pronounced teacher role in the learning process. These lower levels of inquiry are distinguished by the extent of teacher involvement, with the teacher providing scaffolding and guidance throughout (Banchi & Bell, 2008). While both types share similarities, structured inquiry exhibits a subtle shift towards learner autonomy, as students are tasked with generating their own explanations from data they have collected (Banchi & Bell, 2008). A notable trend emerges from confirmation to structured inquiry, where teacher responsibilities decrease as learner responsibilities increase. According to Toma (2022), structured inquiry serves as a crucial stepping stone, equipping learners with fundamental scientific skills like investigation and data gathering, which are essential for tackling more complex inquiries in higher-level inquiry approaches.

Thirdly, guided inquiry involves teachers providing research questions, which learners then investigate to gather evidence for conclusions. Banchi and Bell (2008) concur, noting that teachers' roles are limited to providing research questions, while learners assume responsibility for setting up investigations, conducting experiments, and drawing conclusions. This model exhibits a further reduction in teacher involvement and a corresponding increase in learner autonomy. In contrast to structured inquiry, guided inquiry engages learners more extensively in the learning process, fostering scientific skills like experiment design and execution (Banchi & Bell, 2008). This approach aims to guide learners through the inquiry process, channeling them towards evidence-based learning. While Jerrim et al. (2019) acknowledge potential benefits, such as preventing learner overwhelm, they question whether guided inquiry aligns with the fundamental principles of inquiry, which emphasize learner agency, knowledge construction, and scientific problem-solving through investigations. This debate surrounding guided inquiry's authenticity as an inquiry approach warrants further investigation, a topic beyond the current scope.

Lastly, open inquiry represents the pinnacle of inquiry-based learning, where learners assume complete ownership of their scientific exploration (Toma, 2022). In this autonomous approach, learners formulate research questions, design experiments, collect evidence, and present findings, with teachers providing minimal assistance (Banchi & Bell, 2008). While literature acknowledges that initial learner resistance, proper orientation can lead to productive engagement and deep understanding. Jerrim et al.'s (2019) study supports this, showing that guided inquiry improves assessment performance. The literature highlights the crucial role of teacher involvement in preventing learner overwhelm and ensuring effective inquiry (Jerrim et al., 2019). Teachers must strategically select appropriate inquiry forms and learning cycle models, comprising connected phases that break down the complex scientific process, to maximize learner support and emphasize key scientific inquiry features (Mupira & Ramnarain, 2018).

Research highlights the challenges teachers face in implementing inquiry-based approaches in their science lessons despite curriculum recommendations. In South Africa, studies by Mamombe et al. (2020), Mupira and Ramnarain (2018), and Penn et al. (2021) identify infrastructure limitations, inadequate resources, poor teacher training, and lack of support as significant obstacles to implementing inquiry-based teaching and learning (IBTL) in science classrooms. These findings underscore the need for systemic support and resources to effectively empower teachers to implement inquiry-based approaches in science education.

3 Methodology

This study recruited Grade 10 Physical Science learners from four South African high schools as research participants. These learners were from under-resourced educational environments, marked by constraints in material and human resources, which can potentially impact the quality of science education and learner outcomes. The study employed a guided inquiry approach, where learners participated in hands-on and minds-on activities, including group discussions, observations, experiments, and result presentations. To gather in-depth insights, semi-structured focus group interviews were employed, leveraging the benefits of collective discussion and peer interaction (Creswell & Poth, 2016). As noted by Creswell and Poth (2016), focus groups facilitate the collection of rich qualitative data efficiently. The interviews followed a funnel structure, commencing with open-ended questions to stimulate participants' thoughts and encourage honest responses (McMillan & Schumacher, 2010). The primary objective of these interviews was to explore learners' perceptions of their learning experiences with inquiry-based chemical change lessons. Interviews (Creswell & Poth, 2016) constituted a vital methodological tool for collecting rich qualitative data. While often maligned as time-consuming and analytically challenging, interviews offered a unique epistemological advantage, providing unparalleled data validity since they emanated directly from the participants' own voices.

A purposive sampling strategy was employed to select eight learners from each class, constituting four focus groups. This yielded a total of 32 learners participating in the focus group interviews. The interview protocol was informed by the perceptual indicators with additional questions incorporated to explore learners' cohesiveness, cooperation, teacher support, confidence in the topic, and knowledge gain. Each interview session lasted approximately 60 minutes, allowing participants ample time to share their experiences without feeling rushed. This deliberate allocation of time implies that generous time allocation in qualitative data collection enhances the credibility and validity of the study (Creswell & Poth, 2016). Furthermore, all interviews were audio recorded, with participants' informed consent obtained before recording (McMillan & Schumacher, 2010).

A qualitative content analysis was employed to analyze the interview data to uncover learners' perceptions of their learning experiences with chemical change under inquiry-based pedagogy. The audio recordings were transcribed verbatim, and the resulting data was subjected to a rigorous coding process guided by both priori and emergent themes. Coding (McMillan & Schumacher, 2010) was systematic, and it involved the careful reading and division of data into meaningful analytical units, which were then labeled with symbols or descriptive terms. Following coding, the data was organized into logical units, which were then categorized into emergent themes. These facilitated a rich interpretation of the findings.

The transcribed data from the focus group interviews underwent thematic analysis guided by the five-step framework outlined by Clarke and Braun (2012). Initially, the researcher engaged in acquaintance and immersion, actively participating in the interviews to foster a deep understanding of the topic and elicit rich data from participants through clarifying questions, encouraging equal participation, and maintaining topical focus. Next, the researcher identified and coded themes, aligning them with the predefined indicators, including learners' confidence, teacher support, cohesiveness, and knowledge gain. Two additional themes emerged from the coded data: the practical nature of science and teaching style. The researchers then conducted a coding process, assigning codes to repeated and common words and phrases, ensuring comprehensive analysis and interpretation of the data. Further analysis and explanation revealed the two emerging themes, increasing the total to six. Finally, the researchers consolidated individual code interpretations, seeking common ground, providing explanations, and defining concepts, thus verifying the findings.

The identified codes were then linked to a priori themes, developed prior to data examination, drawing on existing literature and studies (McMillan & Schumacher, 2010). A priori themes served as a conceptual framework, facilitating the coding process and enabling the exploration of existing theories and expanded upon them. To avoid the limitations of confirmatory bias, the researcher remained open to emergent themes, allowing new insights to arise during the coding process. The qualitative data analysis was subsequently separated, with initial analysis focused on pre-defined themes, followed by an examination of emergent themes, culminating in a comprehensive summary of the entire qualitative process.

Table 1: Themes and questions

Theme	Explanation	Questions Asked
Learners' Confidence	Self-confidence is a crucial aspect of effective learning, as learners with high self-confidence are more likely to develop their abilities and perform well academically	• Did you enjoy learning chemical change? Elaborate. • Are you confident enough to share what you learned about chemical change? Elaborate.
Teacher Support	Teacher support is essential for learner motivation and academic success. Effective teachers question, facilitate, provide feedback, and motivate learners during the learning process	• Was there a point during the chemical change lessons that you felt lost? How did you overcome this? • Do you believe there was sufficient teacher assistance during the lessons? Explain.
Learners' Cohesiveness/Cooperation	Learners must work effectively in groups and individually, engaging in collaborative learning and sharing responsibilities	• Did you play a role during group discussions in class? Elaborate. • Were you actively participating in class during the chemical change lessons? If not, why?

4 Results and Discussion

The findings of this study are interrogated through the lens of emergent themes, as delineated in Table 1, which serves as a conceptual framework for unpacking the complexities of the data, thereby facilitating a richer understanding of the phenomena under investigation.

The discussion of the themes unfolds in a logical and coherent sequence, beginning with the learners' confidence, which serves as the foundation for exploring the subsequent themes. Next, the crucial role of teacher support will be examined. Following this, the theme learners' cohesiveness/cooperation is discussed.

As the discussion progresses, two emerging themes will be revealed, which were not initially anticipated but emerged from the data analysis. Firstly, the practical nature of science will be explored, highlighting the significance of hands-on experiences in shaping learners' understanding and appreciation of scientific concepts. Finally, the theme of teaching style will be examined, revealing the profound impact that educators' approaches have on learners' engagement, motivation, and, ultimately, their learning outcomes.

4.1 Learners' Confidence

The group exhibited a prevailing sentiment of enthusiasm towards learning chemical change, with a particular emphasis on the experimental components of the lessons. One learner succinctly captured this sentiment, stating, "I enjoyed the lessons because the practicals clarified concepts that were unclear in our notes." This sentiment was echoed by the majority of learners, who found the experiments to be engaging and effective in facilitating connections between observed phenomena and theoretical concepts presented in their notes and textbooks. This aligns with the principles of inquiry learning, as articulated by Gyampon et al. (2020), who posit that an inquiry-orientated science classroom enables learners to assume an active role in their learning, engaging in investigations, experiments, questioning, and observation to resolve problems and thereby enhancing their critical thinking skills and understanding of scientific concepts. Thus, while learners were actively participating in practical activities, they were, in fact, engaging in inquiry learning, fostering a deeper understanding of chemical change.

The learners exhibited enthusiasm and eagerness to share their understanding of the concepts of chemical change and physical change, demonstrating a high level of confidence in their learning. This observation aligns with the findings of Mupira and Ramnarain (2018), who noted that learners in inquiry-based classrooms tend to exhibit self-confidence and motivation. While the learners generally demonstrated a good understanding of the concepts, correctly distinguishing between chemical and physical changes and explaining the processes involved, some learners still held misconceptions. For instance, one learner defined physical change as the formation of a physical product and chemical change as the formation of invisible products. This definition reveals that, despite their confidence and enthusiasm, some learners still harbor misconceptions that require attention. The overconfidence of some learners may have contributed to their failure to accurately define and observe chemical and physical changes, as Gormally et al. (2009) found that learners with lower confidence during learning tend to achieve better outcomes, while those with high confidence often experience reduced outcomes due to a lack of attention to detail, leading to mistakes and misconceptions.

4.2 Teacher Support

A significant proportion of learners grappled with challenges related to balancing chemical equations, particularly when applying the laws of constant composition and conservation of mass. Initially, they struggled to comprehend how to balance equations using the law of conservation of mass. However, upon further inquiry, it emerged that most learners eventually overcame this hurdle through collaborative learning and group work. Despite acknowledging the importance of teacher support, learners felt that they did not receive sufficient guidance, as the teacher primarily provided textbook references and supplementary notes rather than hands-on assistance. Interestingly, one learner noted that the limited teacher assistance fostered autonomy and self-directed learning, stating, "Although we didn't receive much help from our teacher, we worked independently in our groups and managed to arrive at correct answers, which was a valuable learning experience." This sentiment highlights the potential benefits of learner-centered approaches and peer-to-peer learning in developing problem-solving skills and promoting academic resilience.

Love et al. (2015) argue that an inquiry-orientated classroom environment is characterized by learner-centeredness, where learners engage in meaningful activities that promote autonomy and agency. In such an environment, learners exhibit high levels of participation while the teacher assumes a facilitative role, providing introductory information and resources to support inquiry-based learning. The accounts of Love et al. (2015) suggest that the group was indeed engaged in inquiry-based learning, with the teacher acting as a facilitator and providing learners with the necessary resources to explore and discover concepts. However, some learners expressed a desire for more scaffolding, potentially due to their familiarity with traditional teaching methods and the challenges of adapting to a more autonomous learning approach. As one learner noted, "I think the lessons would be more interesting if the teacher provided more assistance rather than waiting for us to figure it out ourselves." This sentiment resonates with the concerns raised by Khalaf and Zin (2018), who highlight the limitations of inquiry-based approaches in neglecting the finite capacity of individual learners' working memory, potentially leading to reduced information retention. Building on the work of van Uum, Verhoeff, and Peeters (2016), inquiry-based science education emerges as a potent pedagogical approach that fosters engagement and motivation in science learning by empowering learners to design and conduct their own scientific inquiries. The study by Uum et al. (2016) demonstrates that teachers can effectively facilitate learners' progression through the open inquiry process by explicitly addressing the interconnected domains of scientific knowledge, including conceptual, epistemic, social, and procedural aspects, in a phased and systematic manner. This finding underscores the importance of a structured and scaffolded approach to inquiry-based learning, highlighting the critical role of teacher guidance in promoting learners' scientific literacy and cognitive development.

4.3 Learners' Cohesiveness/Cooperation

Learners engaged in vibrant group discussions during the chemical change lessons, demonstrating active participation and enthusiasm. Learners voluntarily described their roles in the discussions, showcasing their agency and engagement. One learner proudly declared, "I was the curious one, always asking questions, discussing, and contributing suggestions!" Another learner highlighted their supportive role, stating, "I assisted my peers when they struggled to recall concepts." Learners enthusiastically shared their roles, including group leaders, scribes, resourceful members, and researchers, indicating a high level of engagement. During these discussions, learners employed critical thinking skills, debating, discussing, and brainstorming together. Most learners reported being actively engaged in most lessons, posing clarity-seeking questions, participating in debates, and contributing during teacher feedback. One learner noted, "I was particularly active during practicals, as I eagerly anticipated the reaction outcomes." Another learner appreciated the autonomy, stating, "The group discussions were interesting because the teacher didn't interfere with our discussions." This learner-centered approach fostered a collaborative learning environment, promoting learner autonomy and agency.

The learners' sentiments indicate that they were actively engaged in their learning process, collaboratively seeking clarification and constructing understanding through peer-to-peer interactions. This aligns with the principles of inquiry-based learning, which emphasizes student-centered activities like group discussions and reflections to foster meaningful and effective teaching and learning (Toma, 2022). Group discussions are a crucial component of science education, as they offer numerous benefits, including the opportunity for learners to articulate their understanding of a topic, receive feedback and validation from peers, and develop essential scientific skills and humanitarian values (Tanaka, 2007). The learners' ability to clearly articulate concepts related to chemical change and their willingness to share their understanding with peers during interviews suggest that they have greatly benefited from the group discussions, demonstrating the efficacy of this pedagogical approach in promoting deep learning and academic achievement.

As we delve deeper into the findings, two intriguing themes emerged from the data, warranting further exploration and discussion. Firstly, the practical nature of science comes to the forefront, highlighting the significance of experiential learning and hands-on activities in shaping learners' understanding and appreciation of scientific concepts. Closely tied to this, the theme of teaching style reveals itself, underscoring the profound impact that educators' approaches have on learners' engagement, motivation, and, ultimately, their learning outcomes. These two emerging themes offer valuable insights into the complex dynamics of science education, inviting us to reconsider the ways in which we teach and learn science.

4.4 The Practical Nature of Science

The learners expressed enthusiasm for their lessons, citing the experiments and group discussions as key factors that contributed to their enjoyment of the lesson on chemical and physical changes. The learners perceived experiments as an integral component of their learning experience, eagerly anticipating the outcomes of the practical activities. This suggests that learners who engage in experiment-based science learning tend to be more engaged and motivated, actively participating in classroom activities. This finding is supported by Annisa and Rohaeti (2018), who discovered that learners taught science through experiments generally enjoy the hands-on experience and have positive reviews of the practical activities. In addition, the findings of this study resonate with the work of Sharpe and Abrahams (2019), who similarly found that students viewed practical work as a valuable and enjoyable aspect of science lessons. Specifically, both studies suggest that hands-on, inquiry-based activities are perceived by students as a positive and engaging way to learn science, fostering a deeper understanding of scientific concepts and promoting a more meaningful connection to the subject matter. This alignment reinforces the notion that practical work is a crucial element of effective science education, and its inclusion can profoundly impact students' attitudes and learning outcomes. This aligns with the principles of inquiry-based learning, which emphasizes experimental activities as a fundamental aspect of the learning process. Through this approach, learners are presented with research questions, guided in formulating hypotheses, encouraged to conduct experiments to test their hypotheses, and supported in conducting literature reviews to explain their findings.

4.5 Teaching Style

The learners perceived their teacher's pedagogical approach as facilitative, allowing them autonomy to explore ideas and construct understanding through group discussions without interference. One learner appreciated the limited assistance, stating, "The less assistance we received from our teacher was beneficial, as we worked independently in our groups and arrived at correct answers despite minimal guidance." This suggests a learner-centered approach, where the teacher acts as a facilitator, providing support and resources while allowing learners to take ownership of their learning. Effective science learning requires a teacher who acts as an initiator and director, facilitating learner-centered inquiry (Donkoh & Amoakwah, 2024) and providing opportunities for independent exploration and problem-solving. The learners acknowledged receiving necessary resources, including printouts, notes, laboratory equipment, worksheets, and textbooks, at the beginning of lessons, which they utilized during activities. During classroom activities, the teacher observed and took notes while learners debated, brainstormed, and answered questions, as one learner described, "We were debating and brainstorming while answering worksheet questions, and the teacher moved around observing and taking notes without interrupting." The learners' accounts suggest the teacher perceived their role as a facilitator, providing scaffolding and resources while observing and addressing potential misconceptions.

In summary, the focus group interviews revealed that learners perceived their learning experience as promoting active engagement, fostering group discussions, and minimizing teacher intervention, ultimately leading to enhanced knowledge acquisition. These findings provide valuable insights into the learners' perspectives on their learning experiences, allowing for a direct connection to be made between their views and the teaching approach employed.

The learners were enthusiastic about their lessons, readily sharing their acquired knowledge with peers without hesitation. The current study's findings are consistent with the research conducted by

Arisujati and Suweken (2020), which demonstrated that students who received instruction through an inquiry-based learning model exhibited superior reasoning skills and higher self-esteem compared to their peers who received traditional instruction. Specifically, the inquiry learning model's emphasis on active exploration, critical thinking, and problem-solving appeared to foster a more profound impact on students' cognitive and affective development, leading to enhanced reasoning abilities and a more positive self-perception. This alignment suggests that inquiry-based learning has the potential to promote deeper learning outcomes and more positive student outcomes, reinforcing the value of this approach in educational settings. During group discussions, learners assumed various roles, relishing the opportunity to discover concepts independently and seeking clarification from peers when needed.

The findings of this study resonate with the research conducted by Hung and Wu (2023), who similarly found that inquiry-based methods empower learners, enabling them to take an active role in their learning journey. By embracing inquiry-based approaches, learners are encouraged to engage meaningfully in research, analysis, and classroom activities, fostering a sense of agency and autonomy in their learning process. This, in turn, leads to a more immersive and interactive learning experience, where learners are motivated to explore, investigate, and construct their own understanding of the subject matter. The alignment with Hung and Wu's discovery highlights the potential of inquiry-based learning to transform learners from passive recipients of information to active participants in the learning process, leading to a more engaging and effective educational experience.

Learners felt under-supported by their teachers but perceived the limited teacher involvement as liberating, fostering independence and encouraging more extensive reading and peer discussion to attain desired answers. The current study's findings harmonize with Antonio and Prudente's (2024) argument that inquiry-based approaches profoundly impact student learning, cultivating independent thinking, higher-order cognitive skills, and active engagement. In stark contrast, traditional teaching methods often focus on teacher-directed instruction and rote memorization, which can stifle students' autonomy, creativity, and critical thinking abilities. By adopting inquiry-based strategies, educators can shift the learning paradigm, empowering students to take ownership of their learning journey, explore complex concepts, and develop a deeper understanding of the subject matter. This alignment reinforces the notion that inquiry-based learning is a potent catalyst for fostering intellectual curiosity, creativity, and critical thinking, ultimately preparing students for success in an increasingly complex and interconnected world.

5 Limitations

This study has several limitations that should be acknowledged. The small sample size and single-method approach may limit the generalizability and depth of the findings. Additionally, the study's focus on learner perspectives, without fully exploring teacher experiences and challenges, provides an incomplete picture of inquiry-based learning. The study's contextual factors, such as the specific school environment and curriculum, may also impact the findings, making it difficult to apply them to other settings. Furthermore, the short-term focus and reliance on self-reported data may not capture the full complexity of learners' experiences and the long-term impact of inquiry-based learning. Finally, the study may not fully explore the challenges and difficulties learners faced during the process, potentially overlooking important aspects of the inquiry-based learning experience.

6 Conclusion

In conclusion, this study demonstrates the efficacy of inquiry-based learning in fostering a learner-centered environment that promotes active engagement, autonomy, and conceptual understanding in science education. By empowering learners to take ownership of their learning, inquiry-based approaches encourage critical thinking, problem-solving, and collaboration. The findings highlight the importance of shifting from traditional teacher-centered methods to learner-centered inquiry-based approaches, which can lead to deeper understanding and improved academic achievement.

The study's outcomes have implications for science education, emphasizing the need for teachers to adopt facilitative roles, providing scaffolding and support while allowing learners to explore and discover concepts independently. By embracing inquiry-based learning, educators can create dynamic learning environments that cultivate curious, creative, and critically thinking individuals equipped to succeed in an increasingly complex and rapidly changing world.

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