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Philosophical Underpinnings of Critical Thinking in Life Science Education

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Abstract: This study examines the philosophical foundations and pedagogical realities that influence the development of critical thinking in Life Sciences education. Guided by constructivist, self-determination, and cognitive load theories, the research explores how philosophical perspectives shape learners' reasoning, autonomy, and real-world application of knowledge. Using a qualitative approach, data were collected from six schools through interviews, focus groups, observations, and questionnaires. The findings highlight a significant tension between the philosophical ideals of inquiry-based learning and the dominant content-driven examination-focused practices. Although teachers recognise the importance of fostering reasoning and reflection, systemic constraints, such as syllabus pressures and limited resources, hinder implementation. The study suggests a philosophical shift from Essentialism towards Constructivism and Critical rationality, emphasising ethical reasoning, inquiry, and learner autonomy to transform Life Sciences education into a platform for critical engagement and intellectual independence.

Keywords: Cognitive Load Theory, Constructivism, Critical Thinking, Life Sciences Education, Pedagogy, Philosophical Foundations, Self-Determination Theory.

Introduction

Concerns about the limited development of critical thinking skills among South African learners in Life Sciences education have become an increasingly prominent issue within the academic and educational landscape (Munasi & Msezane, 2024). Despite its importance in developing scientific literacy and inquiry, the teaching of Life Sciences in most high schools remains ineffective. In many historically disadvantaged contexts, it remains dominated by rote learning, memorisation, and examination-focused instruction. This trend reflects deep-rooted legacy, both philosophical and pedagogical, inherited from Bantu Education (Ndimande, 2013), where obedience and memorising facts were valued more than fostering intellectual independence and reasoning (Dlamini, 1990; Waghid & Davids, 2018).). Even after 30 years of change in the educational system, local ways of learning are undervalued by imported pedagogies, which also foster an educational culture that does not support the development of critical thinking among the previously marginalised (Pietersen, 2021; Pietersen, 2024). Today's rapid environmental, technological, and global health changes demand that Life Sciences

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classrooms become environments that promote reasoning, ethical judgment, and problem-solving skills relevant to scientific citizenship (Almulla, 2023).

The issue grounding this research is the persistent discrepancy between the philosophical ideals of critical thinking, inquiry-based learning, and the reality of content-driven, compliance-oriented classroom practices. Although the national curriculum advocates for higher-order cognitive engagement (CAPS, 2011), classroom practices remain strained by pressures from syllabi, high-stakes assessments, and teachers without the professional preparation to engage learners in discourse and reflective practice. Thus, Life Sciences education has largely resulted in a persistent failure to develop learners' scientific reasoning, evidence-based justifications of arguments, and the application of knowledge in real-life contexts (Papaneophytou & Nicolaou, 2025). This shortcoming undermines both academic achievement and democratic participation at the same time (Koderman, 2024).

This study aims to assess the extent to which the philosophy that underpins critical independent thinking in Life Sciences education influences learners' academic achievement. An investigation of how philosophical orientations toward knowledge, values, and pedagogy influence the development of critical thinking in the teaching and learning of Life Sciences within Johannesburg North high schools. The focus was on determining whether current teaching practices promote inquiry, reflection, and learner independence, or still reproduce essentialist traditions by placing too much emphasis on the recall of facts. The study was guided by the following research question: *To what extent does the underlying philosophy of independent thinking in Life Sciences education influence learners' academic achievement?*

Against this background, the study explores the philosophical foundations of Life Sciences education, identifying how epistemological and axiological assumptions, along with pedagogical approaches, shape the development of critical thinking. By investigating classroom practices, teacher beliefs, and curriculum documents, it aims to add to an emerging discourse on reconceptualising Life Sciences education as a discipline that nurtures intellectual independence, ethical reflection, and contextually framed scientific reasoning.

A qualitative research design was adopted, with 18 Life Sciences educators and 36 learners from six public high schools participating. Multiple data collection methods were used, including semi-structured interviews, classroom observations, questionnaires, and document analysis, to ensure data richness and triangulation. Participants were selected based on their experience and relevance to the study focus. Data was analysed using Braun and Clarke’s (2006) thematic analysis framework, which helped identify recurring patterns in critical thinking practices. This study aimed to identify the factors that constrain effective critical thinking promotion and to indicate areas of opportunity that could enhance teaching and learning. The findings have important implications for policy, curriculum design, and professional development, which can contribute to improving Life Sciences education.

Literature review

A review of related literature shows that, supported by constructivist, self-determination, and cognitive load theories, critical thinking enhances learners' cognitive flexibility, motivation, and problem-solving skills (Piaget, 1973; Deci & Ryan, 2000; Sweller, 1988). Inquiry-based and problem-centred pedagogies have been found to improve reasoning and engagement by enabling learners to connect scientific concepts with societal issues (Venter & Petersen, 2023; Pham, 2024). However, studies by Alsaleh (2020) and Majawa et al. (2024) confirm that actual implementation remains weak due to structural and philosophical constraints within schools.

Overview of Philosophical Foundations of Critical Thinking in Life Sciences Education

The philosophical underpinnings of critical thinking in Life Sciences education are fundamental in defining the cognitive, ethical, and scholarly development of learners (Ciubotariu, 2024). These underpin how learners approach content, consider complex information, and apply their knowledge in real-world contexts. As Al-Kamzari and Alias (2025) put it, the philosophy of critical thinking is directly linked to academic success, as it fosters intellectual autonomy and deeper conceptual understanding. Mollaebrahim et al. (2025) go on to say that such a philosophical engagement strengthens learners' cognitive processes, promotes intellectual self-regulation, and sharpens the reasoning patterns essential to scientific inquiry.According to Ennis (2018:166), critical thinking is defined as "reasonable, reflective thinking focused on deciding what to believe or do," which demonstrates that the process is deliberate and logical. This definition emphasises that arguing and presenting evidence are necessary to make decisions about various matters-and therefore applies to the Life Sciences learner, because that learner is constantly engaging with complex biological phenomena.

Inquiry-Based and Problem-Based Learning as Drivers of Critical Thinking

A considerable amount of research emphasises inquiry-based and problem-based pedagogies to develop critical thinking (Zulaeha & Formen, 2024). Siphukanyo and Olawaye (2024) further indicate that learners who are good at problem-solving can apply scientific principles to real-life problems, as expected in Life Sciences. Inquiry-based learning allows learners to ask scientific questions, investigate evidence and data, and formulate logical conclusions (Venter & Petersen, 2023; Uthaikanchanakul, 2025). Each of these steps requires learners to question assumptions, work with complexity, and reason using evidence. According to Wada (2025), collaborative learning environments in which learners interact with peers and educators strengthen reasoning, communication, argumentation, and perspective-taking. This environment supports the selection, evaluation, and synthesis of relevant information during inquiry, further developing critical thinking competencies.

Motivational and Cognitive Benefits of Inquiry-Driven Pedagogies

The motivational and cognitive benefits of inquiry-based learning are well-documented. Odhiambo (2022) specifically cites the intrinsic satisfaction learners receive through discovery-based learning, therefore increasing engagement and curiosity. However, despite the general support for inquiry-based learning, Arifin et al. (2025) argue that more research is needed to identify which specific inquiry components most effectively bolster critical thinking. Singha and Singha (2024) identify inquiry-driven pedagogies that excite autonomous investigations into sustainability issues. Sam (2024) also presents evidence that inquiry-based learning can lead to transformative teaching practices and learner outcomes. Similarly, Pham (2024) calls for problem-centred pedagogies that require responsibility, collaboration, and real engagement with scientific challenges. Such pedagogies are particularly vital in Life Sciences, which engage learners with current global issues such as health crises, biodiversity loss, and climate change (Atmojo et al., 2025).

Philosophical Perspectives on Science, Reasoning, and the Digital Era

From this perspective, science is framed not only as knowledge, but also as a way of reasoning, inquiry, and technological engagement (Chakravartty, 2023). From this perspective, learners can use scientific reasoning and digital technology to solve biological problems, such as disease management and sustainability. Jamil et al. (2024) add that when living in the modern information era, characterised by high speeds of data flow, learners have to develop sophisticated analytical skills in order to synthesise interdisciplinary knowledge and grasp complicated scientific issues.

Empirical Support for Integrating Philosophical and Scientific Methodologies

Empirical evidence reinforces the value of integrating philosophical reasoning with Life Sciences pedagogy. Reyes and Regala (2025) support such integration, noting its positive impact on critical thinking skills. Wicaksono (2020) affirms that a philosophical-scientific approach enhances higher-order cognitive skills, such as creativity and analytical problem-solving. Pinar et al. (2025) add that with the application of scientific methods, logical reasoning, and creative thinking become better developed to enable learners to approach complex issues in a consequential manner. Obidovn (2024) further supports approaches such as nurturing reflective engagement and deepening scientific understanding.

Pedagogical Frameworks Enhancing Critical Thinking: PBL, Metacognition, and Collaboration

Critical thinking itself can be enhanced by various pedagogical frameworks grounded in philosophical foundations. Juhji and Mansur (2020) make a valid connection between critical thinking, scientific literacy, and mastery of biological concepts. Razak et al. (2022) identify problem-based learning as one of the strategies to improve collaboration, communication, and global literacy skills necessary for critical thinking. Gavgani et al. (2021) demonstrate notable progress in learners' analytical and reasoning skills after PBL interventions. Metacognitive strategies also play an important role. Rivas et al. (2022) illustrate how self-monitoring, reflection, and cognitive regulation enhance problem-solving skills and deepen learning. These help learners assess their thinking, guide cognitive processes, and adopt a more conscious approach to scientific investigation.

Gaps Between Philosophical Theory, Classroom Practice, and Learner Underperformance in Life Sciences

Large implementation gaps remain at the classroom level. Alsaleh (2020) explained that life science instruction remains content-heavy with too little attention to critical inquiry, whereas Siregar (2025) mentioned several discrepancies between the recommended inquiry, problem-based, and metacognitive practices and their implementation in schools. The main challenges include a deficiency in the philosophical grounding of teachers; limited pedagogical skills for higher-order thinking; lack of guidelines for the implementation of inquiry in resource-constrained settings; overcrowded classes; limited laboratory facilities; insufficient integration of technology-enhanced critical thinking; and scarcity of longitudinal studies and South Africa-specific ones-especially in Johannesburg North District, where underperformance in Life Sciences is noted.

In view of this, greater emphasis should be placed on teacher preparation, contextualised pedagogical models, and sustainable instructional strategies. Since the literature strongly supports embedding critical thinking into the teaching and learning of Life Sciences, inconsistent or partial implementation, particularly within the FET band or historically disadvantaged contexts-creates a critical gap to which this study is responding by looking into the philosophical and practical dimensions underlying an absence of critical thinking in Life Sciences education in Johannesburg North high schools.

The deeper philosophical grounding is raised by the performance data in the district from 2021 to 2023. Grade 12 Life Sciences have consistently remained low, with pass rates hovering around 77% and over 1,000 learners failing annually, despite modest increases in candidature. The pass rate rose modestly to 80.4% in 2024 but remained dismal for a large proportion of the learners. These performance disparities thus suggest systemic problems with Life Sciences education, from conceptual pre-exposure to under-prepared conditions within ineffective pedagogical approaches, which place added impetus on the study of the philosophical assumptions underpinning teaching and learning in the subject.

With the above arguments and debates in mind, we consider the extent to which the underlying educational philosophy influences learners' academic achievement. By investigating this relationship, the study sought to move beyond theoretical ideals and connect specific philosophical orientations, such as essentialism or constructivism, to concrete learning outcomes. Consequently, the findings reveal how a misalignment between the espoused philosophy of critical thinking and actual teacher-centred practice creates a significant barrier to achieving higher academic performance.

Theoretical Framework

This study employs a multi-theoretical framework combining constructivist theory (Piaget, 1973; Vygotsky, 1978), self-determination theory (SDT) (Deci & Ryan, 2000), and cognitive load theory (CLT) (Sweller, 1988) to explore the philosophical foundations of critical thinking in Life Sciences in high schools within the Johannesburg North district. The integration of these three theories aims to offer a comprehensive basis for examining the philosophical roots of critical thinking in Life Sciences education in Johannesburg North high schools. This approach is also justified by the complex and multidimensional nature of critical thinking, which encompasses cognitive, motivational, and philosophical aspects. These theories facilitate a shift from Essentialism (Bagley, 1939), which posits that education should focus on mastering core disciplinary knowledge and teacher-centred instruction. Although essentialism ensures curriculum coverage and factual understanding, it often restricts opportunities for inquiry, autonomy, and reflective judgement, contributing to the critical thinking deficiencies observed in Life Sciences (Pérez, 2024).

Constructivism and Motivational Approaches to Critical Thinking in Life Sciences Education

The theories used in the study provide a comprehensive understanding of the philosophical foundations of critical thinking in Life Sciences education in the Johannesburg North District (Villeneuve, 2024). Constructivist theory views learners as active participants who construct knowledge through experience and interaction. This promotes inquiry, problem-solving, collaboration, and higher-order thinking (Mills et al., 2006; Uthaikanchanakul, 2025). SDT offers a motivational perspective, focusing on autonomy, competence, and relatedness, which encourage engagement, self-regulation, and deeper learning (Ngema & Motlhabane, 2025). CLT focuses on managing intrinsic, extraneous, and germane cognitive load to optimise working memory. This management helps to retain and apply complex scientific concepts (Sweller, 2018). Integrating these theories provides a clear framework for analysing how teaching methods, learner motivation, and cognitive processes interact to influence critical thinking outcomes. This approach allows educators to design inclusive, context-based lessons that balance learner-centred strategies with structured guidance. It also caters to learners from varied socio-economic backgrounds and promotes measurable development in critical thinking skills. The resulting theoretical framework defines critical thinking as a product of the interaction among cognitive ability, motivation, and learner-centred instruction (Pietersen, 2024). This offers a strong basis for analysing and addressing the philosophical underpinnings of critical thinking in Life Sciences education.

Philosophical Underpinnings of Critical Thinking and Learning in Life Sciences Education

The findings of the study, Philosophical Underpinnings of Critical Thinking in Life Sciences Education, ultimately reveal a direct and consequential relationship between' implicit philosophical approaches of teachers and concrete indicators of the' academic achievement of learners. The persistence of essentialist, teacher-centred pedagogy, focused on rote memorisation, not only limits epistemic engagement but also manifests in measurable academic outcomes such as superficial content recall and an inability to apply knowledge to novel problems (Pretorius, 2023). In contrast, classrooms where constructivist and critical rationalist ideals were approximated—through dialogic pedagogy, autonomy-supportive practices, and scaffolded inquiry—demonstrated higher levels of learner motivation, deeper cognitive engagement, and, critically, superior performance on assessments demanding analysis, argumentation, and epistemic justification. However, this philosophically-driven pathway to achievement is critically mediated by systemic inequities (Wilson et al, 2022); the axiological failure to address resource disparities means that the academic benefits of a philosophically-aligned, inquiry-based education remain inaccessible to many learners, thereby perpetuating achievement gaps. Thus, the study concretely demonstrates that bridging the identified philosophical-practical gap is not merely an abstract ideal, but a fundamental prerequisite for fostering the higher-order reasoning skills that underpin genuine academic success in Life Sciences.

Methodology

Research Design: This study used a qualitative research design under the interpretive paradigm to investigate the experienced views of critical thinking, the approaches used in teaching and learning, and how it is internalised in Life Sciences education (Treagust & Won, 2023). The interpretivist approach was used because of its recognition that meaning is socially constructed and obtained from lived experiences. A case study design, multiple cases were used to provide an in-depth understanding that is contextualised about teachers' and learners' although that the learners are the majority of respondents for which perspectives in different school settings unfolded. This allowed identification of patterns and differences in instruction practices, engagement at cognitive levels, and motivational factors that influence the development of critical thinking. The qualitative design further befits the underpinnings philosophy of Constructivism, which emphasises interaction, reflection, and co-construction of meaning as highlighted by the seminal works of Vygotsky (1978) and Piaget (1973).

Sampling and Participants: A purposive sampling technique was used to select participants who could provide rich and relevant information on the research problem (Tajik et al., 2024). The study involved 18 Life Sciences educators and 36 learners drawn from six public high schools in the North District of Johannesburg, Gauteng Province, South Africa. Schools were selected to represent socio-economically diverse contexts, ranging from affluent urban institutions to under-resourced township schools. The selection of teachers and learners was based on their direct participation in the Life Sciences curriculum at the 10-12 level. This diversity ensured the inclusion of multiple perspectives and provided comparative insights into how contextual factors influence the development of critical thinking skills in Life Sciences education. And for us, learners are the majority of respondents to make this study work.

Data Collection Instruments and Procedures: Data collection was conducted through semi-structured interviews, focus group discussions, and classroom observations (Mazhar et al., 2021). Semi-structured interviews with teachers covered their instructional philosophy, pedagogical strategies, and perceptions of critical thinking in Life Sciences. Focus groups have been conducted with learners to understand their experiences, motivation, and perceived challenges in participating in critical thinking activities. Classroom observation allowed the researchers to document actual teaching practice, teacher-learner interactions, and cognitive engagement during Life Sciences lessons. All data collection instruments were developed based on the theoretical framework to ensure they captured the cognitive, motivational, and instructional dimensions of critical thinking development. Data collection lasted six weeks, a duration considered sufficient to observe instructional patterns and learners' participation in class.

Data Analysis Techniques: Braun and Clarke (2006) followed a thematic analysis procedure. Thematic analysis was selected for its flexibility, which is particularly suited to eliciting, analysing, and interpreting patterns of meaning within qualitative data. The six-step process was followed, namely, familiarisation with the data, coding, generating themes, reviewing themes, defining and naming themes, and writing. ATLAS.ti software was utilised to systematically manage, code, and organise the qualitative data throughout the research. Themes emerged inductively from the data but were interpreted through the philosophical lens underpinning the study: the principles of Constructivism (knowledge construction); Self-Determination Theory (motivation and autonomy); and Cognitive Load Theory (processing demands). Triangulation between sources improved the credibility and validity of the findings.

***Ethical Considerations*:** Ethical clearance was obtained from the University of South Africa Ethics Committee. The Gauteng Department of Education gave permission to conduct research in public high schools. In addition, permission was sought and granted from participating schools, and informed consent was obtained from all participants. For learners under 18, parental and student consent were obtained. Participants were assured that their responses would be kept confidential; participation was voluntary, and they had the right to withdraw at any time without penalty. Pseudonyms were assigned to protect participants' identities, and all data were stored in password-protected digital files at a location accessible only to researchers. The study adhered to ethical research standards, ensuring respect, beneficence, and justice throughout the research process.

Results and Findings

The analysis yielded four major themes that reflect the interaction among teachers' instructional practices, learners' participation, and the embedded philosophical orientations driving Life Sciences education. These four themes denote both the opportunities and limitations involved in fostering critical thinking within the varied schooling environments of the Johannesburg North District (Wickham, 2016).

Theme 1: Limited Conceptualisation of Critical Thinking

In schools, both educators and learners demonstrated an inconsistent understanding of what constitutes critical thinking within the Life Sciences curriculum. Although most teachers equated critical thinking with “application” or “problem-solving,” few articulated it in terms of reasoning, argumentation, or evidence-based justification. For example, some teachers described it as “getting learners to think beyond the textbook,” while others viewed it narrowly as “answering higher-order questions.” This limited conceptualisation indicates a philosophical gap-teachers tend to approach knowledge from an essentialist or positivist standpoint rather than a constructivist one. Consequently, lessons often focused on factual recall rather than epistemic inquiry. The finding echoes Alsaleh (2020) and Waghid & Davids (2018), who note that without philosophical grounding, critical thinking remains superficially addressed in science classrooms.

Theme 2: Teacher-Centred Pedagogy and Restricted Inquiry

Classroom observations revealed that instruction in the life sciences remains predominantly teacher-centred, with limited learner autonomy or inquiry-based engagement. Teachers often relied on lecture and note-taking methods, driven by the pressure to complete the syllabus and prepare learners for examinations. Inquiry-based or argument-driven learning activities were rare, and when attempted, they were often limited by time, large class sizes, or limited resources. This finding reflects a misalignment with Constructivist principles**,** which advocate for learner-centred, exploratory, and dialogic teaching approaches. The observed emphasis on content coverage over conceptual engagement impedes learners' ability to construct meaning and develop critical reasoning skills. As an educator noted, "We would like to give learners time to discuss and explore, but the curriculum is too packed, and we have to rush through the content." " This aligns with studies by Majawa et al. (2024) and Venter & Petersen (2023), which highlight systemic pressures and curriculum rigidity as key barriers to fostering critical thinking in Life Sciences classrooms.

Theme 3: Motivation and learning autonomy

Focus group discussions showed that learner motivation is crucial for critically engaging with life sciences content. The learners demonstrated greater enthusiasm and cognitive engagement when the teachers nurtured a supportive, autonomy-oriented environment, in line with Self-Determination Theory (SDT). The learners in such settings described feeling "respectful" and "trusted to think for themselves," which led to increased curiosity and greater understanding. In contrast, in environments where instruction was highly controlled or solely examinational, learners reported disengagement and anxiety. This indicates that autonomy support, feedback, and meaningful contextualisation of scientific concepts strengthen the' intrinsic motivation—an essential condition for critical thinking. The finding aligns with Deci and Ryan's (2000), assertion that intrinsic motivation thrives when autonomy, competence, and relatedness are promoted within the learning environment.

Theme 4: Cognitive Overload and Instructional Design Challenges

Analysis of classroom practices also revealed issues related to Cognitive Load Theory (CLT). Many learners reported difficulty processing complex Life Sciences concepts due to excessive content density and rapid pace. Teachers confirmed this challenge, noting that the subject's abstract and information-heavy nature often overwhelms learners. Observations showed that when lessons integrated scaffolding, visual aids, or fragmented explanations, learners demonstrated stronger conceptual retention and greater participation in discussions. In contrast, unstructured inquiry tasks without clear guidance often led to confusion and surface-level engagement. This finding underscores the importance of balancing constructivist inquiry with cognitive structure**.** Effective teaching of critical thinking requires reducing extraneous load while maintaining a germane cognitive effort, allowing learners to process, question, and integrate information meaningfully.

Theme 5: Contextual and Systemic Constraints

Socio-economic disparities among schools in the Johannesburg North District markedly influenced teaching quality and cognitive engagement of learners. Under-resourced schools faced challenges such as large class sizes, limited laboratory equipment, and insufficient access to teaching aids. These constraints not only restricted inquiry-based learning but also perpetuated inequities in opportunities for higher-order thinking. Teachers in resource-constrained settings expressed frustration at their inability to implement innovative methods, noting that policy expectations often clash with practical realities. This highlights the axiological tension within Life Sciences education between the ideal of equitable, inquiry-driven learning and the lived conditions of inequality (Pietersen et al. 2023). It reinforces the argument by Waghid & Davids (2018) that philosophical ideals of justice and compassion in education must be grounded in social realities.

Discussion

The findings of this study highlight a persistent gap between the philosophical ideals of Life Sciences education and the realities of classroom practice. Although teachers acknowledge the value of critical thinking, their instructional approaches remain largely teacher-centred and content-driven, reflecting an underlying essentialist and positivist philosophy rather than a constructivist or critical rationalist orientation. This misalignment limits the opportunities of learners to engage in reasoning, argumentation, and reflective inquiry, the very processes central to the epistemology of science education (Chakravartty, 2023; Alsaleh, 2020). From a constructivist perspective, learning in Life Sciences should promote active knowledge construction through exploration and dialogue. However, the dominance of rote instruction, memorisation, and examination-oriented assessment suppresses inquiry-based learning. The' limited philosophical grounding of teachers contributes to this challenge, as many perceive critical thinking as a mere problem-solving rather than a deeper process of epistemic justification and reflection. This finding supports earlier research by Majawa et al. (2024) and Venter & Petersen (2023), which argues that critical thinking cannot flourish without a shift from transmissive to dialogic pedagogy.

The study also demonstrates that learner motivation and autonomy, as outlined in Self-Determination Theory (Deci & Ryan, 2000), are critical determinants of cognitive engagement. Classrooms that foster autonomy, relatedness, and supportive feedback enabled learners to participate more actively and think more critically. These findings affirm that cultivating critical thinking is not only a cognitive process but also an affective and motivational one. Insights from Cognitive Load Theory (Sweller, 1988) illuminate the cognitive barriers to critical engagement. When instruction is overloaded with factual information or poorly scaffolded inquiry tasks, learners experience an extraneous cognitive load, leading to surface-level understanding. Effective instructional design must, therefore, balance cognitive challenge with clarity, supporting the germane processing necessary for deep, reflective learning. Contextual and systemic inequities remain significant barriers. The coexistence of well-resourced and under-resourced schools within the same district perpetuates disparities in access to high-quality, inquiry-based education. This reality underscores the axiological dimension of Life Sciences education and its ethical responsibility to ensure equitable opportunities for all learners to develop higher-order reasoning skills.

Recommendations

The study sought to investigate the philosophical underpinnings of critical thinking in Life Sciences education and its implications for the development of critical thinking among teachers and learners in the North District of Johannesburg. The findings indicate continued disjuncture between the inquiry-driven, ethical, and reasoning-based philosophical moorings of Life Sciences and the perpetuation of dominant classroom practices reliant on memorisation, rote learning, and examination-oriented teaching. Teachers' partial understanding of critical thinking, coupled with curriculum pressures and inequities in resource distribution, continues to limit learners' opportunities to reflect, reason, and think analytically.

The results further underscore how such a purposeful approach to Life Sciences education extends well beyond an assumption of learners' assimilation of factual knowledge, embracing the epistemological nature of science as inquiry and, with it, the ethical dimensions of biological knowledge and the pedagogical importance of active, learner-centred engagement. Constructivism, Self-Determination Theory, and Cognitive Load Theory collectively illustrate how effective Life Sciences teaching can foster autonomy, motivation, and cognitive clarity, the very conditions under which learners develop to become critical and scientifically literate. This implies a movement away from Essentialism's emphasis on fixed truths toward constructivist and critical rationalist positions, which allow learners to question, test, and build knowledge.

This would involve strengthening teacher preparation in the philosophical underpinnings of Life Sciences education, adopting inquiry-based pedagogies such as Project-Based Learning and Argument-Driven Inquiry, and redesigning assessments to assess reasoning, ethical reflection, and conceptual understanding. Ensuring equity in resources and continuous professional development will be necessary to support teachers in these enactments of philosophies. Langeveldt & Pietersen (2023) agree that ongoing professional development should equip teachers and institutions with data-analysis skills, evidence-based decision-making strategies, and a mindset of continuous improvement for effective learning performance. They added that this targeted development enhances educators' competencies and cultivates a more responsive, positive school environment. Thus, closing the gap between theoretical ideals and everyday classroom realities depends on the development of critical thinkers applying scientific reasoning to solve real-world problems.

Limitations and Future Research

The limitations mentioned above should be considered when interpreting the findings of the present study. The research was carried out in one district, Johannesburg North, which limits the generalisability of the results. The experiences, challenges, and philosophical orientations found in this particular context could differ significantly from those experienced by other districts or provinces, and thus the findings cannot be assumed to be representative of the national landscape (du Plessis, 2015). This qualitative research design involved interviews, classroom observations, questionnaires, and document analysis, yielding rich, detailed data. However, it also introduced biases inherent to this methodology. For example, participants may have provided socially desirable responses, particularly regarding critical thinking, teaching practices, and curriculum implementation. The time constraints associated with classroom observation may also have limited the ability to capture typical instructional practices.

Other limitations were related to the study's sample size and sampling strategy. Purposive sampling ensured that people with relevant experience and expertise participated; however, the relatively small numbers of both teachers and learners reduce the extent to which the findings can be generalised. The perspectives collected give voice to the experiences of a specific group and may not represent the full diversity of views in other educational settings. The constructs explored-philosophical underpinnings and critical thinking are perforce complex and multi-dimensional. Capturing the full depth of participants' orientations and practices within a limited interview time and classroom access proved difficult; not all conceptual nuances could be explored (Langsford, 2021). Resource and time constraints further influenced data collection, as researchers could access participants only during certain periods of the school year, which might have affected respondents' openness and engagement. In the absence of longitudinal follow-up, the reliance on self-reported data does not accurately show the shifting nature of teaching and learning.

Despite these limitations, the study opens various avenues for prospective research. The geographical scope could be expanded to cover more districts or provinces, where comparative analyses would enhance the generalisability of the findings. Future studies could employ mixed-methods or longitudinal research designs that capture both the depth and breadth of data, as well as changes in teachers' philosophical orientations and learners' critical thinking skills over time (Wong & Luft, 2015). Another possible direction is intervention-based research. Evidence-based strategies for improving Life Sciences education could thus be evaluated through professional development programs with their focus on philosophical foundations, inquiry-based learning, and critical thinking pedagogy.

Such further research might also investigate how curriculum policy, school leadership, and organisational culture influence the development of critical thinking. Understanding how such systemic factors shape teacher beliefs and classroom practice could usefully inform more effective policy and school-level interventions (Leibovitch et al, 2025). Finally, greater emphasis on learner-focused research, inquiring into learners' perceptions, metacognitive development, and engagement with inquiry-based activities, would provide insight into how philosophical orientations manifest in learners' everyday experiences of learning. Such studies would contribute to a more holistic understanding of how Life Sciences education can effectively cultivate critical thinking.

Conclusions

The philosophical reorientation of Life Sciences education is not a luxury but a necessity. It is through the integration of constructivist epistemology, ethical inquiry, and autonomy-supportive pedagogy that Life Sciences can fulfil its transformative purpose of developing learners who think critically, reason ethically, and contribute meaningfully to a complex and uncertain world.

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