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Life Sciences Teachers' IBL Conceptions and Implementation in Laboratories and Digital Classrooms: Implications for Context-Responsive Professional Development

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Abstract. Inquiry-Based Learning (IBL) is widely recommended in science education for its potential to foster learners' scientific inquiry skills, autonomy, critical thinking, and problem-solving abilities, and its adoption has grown steadily as part of curriculum reform. Despite its recognised benefits, the enactment of IBL in many classroom contexts remains uneven, particularly in resource-constrained schools. This study explored Life Sciences teachers' conceptions and implementation of IBL within laboratories and digitally mediated classrooms in disadvantaged public schools. Guided by an interpretivist paradigm and a qualitative approach, the study adopted a multiple-case study design involving ten in-service Life Sciences teachers from the King Cetshwayo District, KwaZulu-Natal, South Africa. Data were collected in April and May 2025 through analysis of documents used in practical investigations, a semi-structured questionnaire, and semi-structured interviews. Data analysis was informed by the Capability Approach (CA), focusing on resources, implementation, associated factors, and outcomes, and followed Braun and Clarke's (2006) thematic analysis procedures. The findings indicate that teachers' conceptions of IBL are minimal and do not align with its theoretical principles, as their practices are predominantly teacher-centred. The teachers' limited pedagogical understanding, low confidence, inadequate professional development, scarcity of laboratory and digital resources, and challenging classroom conditions constrained their abilities to implement an authentic inquiry-based pedagogy. Digital technologies, where available, were insufficient and largely used in non-interactive ways. The study concludes that expanding teachers' capabilities through integrated professional, contextual, and resource-based support is essential for realising IBL's transformative potential. Using the CA, the study shifts the focus from uniform outcomes to what teachers can achieve within their contexts.

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Keywords: inquiry-based learning; Life Sciences teachers; capability approach; teacher professional development; resource-constrained schools; digital technologies

1. Introduction

Inquiry-based learning (IBL) has gained prominence in science education as it promotes an understanding of science as both a process and a product. It encourages learners to actively construct knowledge rather than receive it passively (Chikaluma et al., 2022; Laksana, 2017). In 1994, after its first democratic election, the South African government reformed its education system to align with global trends. Before this period, the system had reflected deep racial inequalities, with black learners experiencing largely rote-based science instruction (Gaigher et al., 2014). The introduction of Curriculum 2005 (C2005) in 1998 marked a shift towards outcomes-based education, which emphasised knowledge construction and higher-order thinking. However, the absence of prescribed content placed considerable demands on teachers, particularly in under-resourced contexts (Govender, 2018).

Subsequent reforms included the Revised National Curriculum Statement (RNCS) in 2003 and the National Curriculum Statement (NCS) in 2006. These reforms aimed to standardise content but failed to improve learner performance, as reflected in Trends in International Mathematics and Science Study results and national examinations. This persistent underperformance revealed a gap between curriculum intentions and classroom practice. The Curriculum and Assessment Policy Statement (CAPS), introduced in 2011, sought to address these shortcomings. CAPS explicitly promoted inquiry through practical work and investigations (Mokiwa, 2014) and introduced practical assessments in Life Sciences (Department of Basic Education [DBE], 2011). It emphasised scientific inquiry as central to learning and aimed to develop critical and creative thinking skills (DBE, 2011).

Despite these policy intentions, effective implementation of IBL remains limited. Many teachers struggle to translate curriculum goals into practice. Studies have recommended sustained professional development and improved teacher preparation to support implementation (Nemadziva et al., 2023; Ramnarain, 2014). Learner performance continues to reflect this challenge. Evidence shows persistent difficulties among learners with inquiry-related skills, such as designing investigations and controlling variables (Kazeni et al., 2018). National diagnostic reports consistently highlight weak performance in scientific investigations (DBE, 2023, 2024, 2025; Reddy et al., 2019).

The Department of Basic Education (DBE) (2023) recognises the problem, reporting that the application of knowledge and the design of investigations require strengthening. These findings indicate a clear gap between the intended curriculum and actual classroom practice, and a research gap with regard to teachers' understanding and implementation of IBL in resource-constrained settings. The problem in such settings is multifaceted. It includes limited resources, inadequate laboratory infrastructure, and teachers' insufficient pedagogical and content knowledge, especially in rural schools (Mupira & Ramnarain, 2018; Ramnarain & Hlatswayo, 2018; Ramnarain, 2023; Nemadziva et al., 2023; Reddy et al., 2019). These constraints hinder the effective enactment of inquiry-based approaches. Against this background, this study aims to inform practice by examining teachers' conceptions and implementation of IBL in both laboratory and digital contexts. The study pursues three objectives: It explores teachers' understandings of IBL; it examines how teachers implement IBL in laboratory and digitalised settings; and it identifies factors influencing implementation in specific contexts.

Accordingly, the study addressed the following questions:
- How do teachers understand IBL?
- How do teachers implement IBL in laboratory and digital contexts?
- What factors affect their implementation?

2. Literature Review
This section critically reviews previous work on IBL, focusing on teachers' conceptualisations, challenges, and technology integration to enhance its implementation. The section also articulates the theoretical lens through which this study is viewed.

2.1 Review of the Literature
2.1.1 Teachers' understanding and conceptualisation of IBL
While IBL is generally regarded as an impactful approach to science education, researchers have expressed concerns about teachers' conceptualisations of it (Akuma & Koenen, 2025). Chikaluma et al. (2022) argue that the way in which teachers conceptualise and interpret IBL is important for its effective implementation. While specific misconceptions about IBL remain unclear, it is known that teachers from urban school's favour IBL while teachers from rural schools favour traditional approaches (Ramnarain, 2014). This observation is supported by Shivolo and Mokiwa (2024), who note that most science teachers still employ traditional approaches to science practical work, in which memorisation plays a central role. This implies that there is a significant lack of understanding about practical inquiry-based science education.

One of the challenges is that many teachers are unaware of the different phases of IBL (Morris, 2025) and of the importance of scaffolding in this approach. The problem is compounded by the fact that scholars use different definitions of IBL (Nicol, 2021). Akuma and Callaghan (2019) argue that the widespread lack of understanding of IBL has implications for learners' understanding, since science teachers fail to translate theoretical inquiry into practical work, which is usually minimal and confirmatory in nature.

However, in their approaches used by Life Sciences teachers, Kazeni and Mkhwanazi (2021) came to a different conclusion, finding that many teachers have quite a significant theoretical knowledge of IBL. It is important to understand the extent to which teachers' conceptions of IBL correlate with implementation in the real classroom context. Currently, the connections between contextual factors, scaffolding challenges, and teachers' practices in the classroom are underexplored, especially in the South African context. This research gap underscores the need for studies that clarify teachers' IBL conceptions across diverse contexts in order to bridge theory and practice effectively.

2.1.2 Types of inquiry-based learning

Banchi et al. (2008) propose a four-level continuum of IBL: confirmatory, structured, guided, and open inquiry, each phase aligning with different levels of learner proficiency. Confirmatory inquiry is highly teacher-directed; learners follow defined steps to confirm known results, developing foundational skills such as observation, experimentation, and analysis (Trna et al., 2012). Structured inquiry provides a research question and procedure, but students are required to generate explanations for the results, which promotes higher-order thinking and the ability to discern connections between evidence and conclusions (Aparicio-Ting et al., 2019; Trna et al., 2012).

Guided inquiry grants students autonomy to design procedures and interpret findings, with teachers facilitating rather than directing, which enhances experimental design and critical reasoning skills (Alston et al., 2020; Aparicio-Ting et al., 2019). Open inquiry allows full student ownership; learners generate questions, conduct investigations, and communicate results independently, which fosters creativity and sophisticated critical thinking (Alston et al., 2020; Aparicio-Ting et al., 2019). Success in higher-level inquiry depends on prior knowledge and cognitive readiness (Trna et al., 2012), making open inquiry more suitable for older or more advanced learners.

Overall, the continuum emphasises progressively developing inquiry skills to cultivate autonomous scientific thinking and investigative competence. However, there is limited empirical evidence on how the progression across different inquiry levels is applicable in Life Sciences in the South African context. This gap highlights the need to explore how teachers navigate different inquiry levels in different contextual settings.

2.1.3 Global challenges associated with inquiry-based learning implementation

Inquiry-based learning (IBL) promotes innovative teaching and develops scientific skills by engaging learners in processes similar to those used by scientists (Bogar, 2019; Chikaluma et al., 2022). It helps shift education from a teacher-centred activity to a learner-centred activity (Gomez, 2025). Despite global recognition, significant challenges continue to hinder its effective implementation. Teachers play a central role in implementing IBL. They must understand its principles to design appropriate learning activities and build confidence, both in themselves and among their learners (Achurra et al., 2024).

Effective implementation requires careful lesson planning, supportive classroom environments, and clear guidance (Gomez, 2025). However, many teachers lack this knowledge. Nicol (2021) highlights teachers' difficulties with inquiry-based instruction. The challenges are more pronounced among novice teachers, who often rely on low-level inquiry approaches such as confirmatory or structured inquiry. Such approaches limit learners' autonomy and restrict the development of key scientific skills, including problem formulation, investigation design, and evidence-based reasoning.

Empirical studies confirm these global concerns. The international StarT programme run by the LUMA Centre in Finland found that many teachers are unfamiliar with IBL concepts (Markula & Aksela, 2022). Research in Spain reported low readiness among pre-service teachers to implement IBL (Achurra et al., 2024). Similarly, studies in the United States showed that teachers prefer demonstrations and basic inquiry practices (Lu et al., 2024). These patterns indicate a persistent reliance on traditional methods.

Overall, global evidence reveals common challenges, including insufficient teacher knowledge, low readiness, and limited use of high-level inquiry practices. These issues undermine the goals of IBL and limit its impact on learner outcomes. They highlight the need for further research on how teachers conceptualise and implement IBL in diverse contexts to strengthen practice and promote meaningful scientific inquiry.

2.1.4 Integration of digital technology to enhance IBL implementation

Many schools lack functional laboratories, which constrains the implementation of IBL. Some teachers have responded by integrating digital technologies into their teaching to support learning, develop 21st-century skills, and enhance both creativity and enjoyment in the classroom. Digital tools include online resources, interactive software, virtual reality, and educational applications that create dynamic learning experiences (Zafee et al., 2025). Mobile learning, virtual laboratories, and augmented reality enhance engagement and interest (Gomez, 2025). These technologies encourage innovation, particularly in resource-constrained contexts.

Research shows that digital simulations and virtual laboratories can support IBL, although access remains uneven (Akuma & Callaghan, 2019). Limited accessibility has restricted meaningful engagement and analysis. Nevertheless, such approaches expand the scope of IBL and highlight the need for context-relevant professional development. However, most IBL practices still occur in conventional laboratory settings (Akuma & Gaigher, 2023; Nemadziva et al., 2023; Ramnarain & Hlatswayo, 2018). Many teachers lack training in using digital technologies, and many schools lack adequate infrastructure (Benkosi & Ramnarain, 2024).

Teacher agency can play an important role in overcoming constraints. For example, teachers with high self-efficacy adopt digital tools independently and integrate them into their practice (Govender & Brás, 2025). However, external constraints often limit these efforts. Overall, digital technologies offer promising alternatives to traditional laboratories, but their effective integration across diverse contexts remains underexplored.

2.2 Theoretical Perspective

2.2.1 Social Constructivism

The study is underpinned by Social Constructivist Theory, as proposed by Piaget and Cook (1954) and Vygotsky (1978). Social constructivism posits that knowledge is actively constructed through social interaction and engagement with the environment, and that learning is mediated by tools such as language, symbols and physical objects. In the classroom, the constructivist approach is evident when learners are actively involved in the learning process (Moemeke et al., 2025; Morris, 2025). It is also evident when learners manipulate objects to conduct investigations.

Both of these aspects are critical to IBL, which encourages learners to actively engage in learning science to discover new knowledge (Morris, 2025). Social constructivism also posits that cognitive development occurs in stages, with scaffolding playing a crucial role as learners progress through different levels of inquiry (Chongo et al., 2021). IBL occurs at different inquiry levels, ranging from dependence on the teacher to complete autonomy to design and conduct experiments. Teachers are expected to provide different levels of guidance as learners navigate different stages of inquiry. This can be achieved through designing IBL-based lessons and activities, providing necessary resources, and creating a conducive environment in which IBL can take place.

2.2.2 Capability Approach

The CA, pioneered by Sen in 1978, is a framework for understanding human wellbeing, focusing on what individuals are able to do and to be (their capabilities) with the resources they have. In education, the approach stresses that it is not enough for learners to be enrolled in school; they also need certain support in order to learn, such as a safe environment and adequate resources. Kuhumba (2018) states that all schools should have access to resources that enable and enhance the teaching and learning experience. This aspect of CA is especially relevant in South Africa, given its poor record in education, characterized by persistent inequalities and government failure to close the gap between resourced and under-resourced schools (Aidoo, 2024).

Given sufficient educational resources, all learners can discover and develop their strengths and capabilities. The CA recognizes that learners have different ways of converting resources into knowledge. Teachers therefore need to be responsive to diverse learning styles, backgrounds and abilities, and to focus on what each learner can do rather than what they cannot do. This position aligns with IBL, which emphasises the process as much as the outcomes in learning (Chikaluma et al., 2022). Moreover, within CA, contextual factors are recognised as central to learning. When designed well, IBL can be adapted to learners' contexts using locally relevant problems and materials, so that science is made accessible and meaningful to all. This study is concerned with the factors that enable teachers' implementation of IBL, and how, even in the midst of unfavourable contextual factors, a sound understanding of IBL can contribute to enhanced classroom practice through the design and implementation of practical investigations.

2.2.3 Integrating the theoretical foundations
Social constructivism forms the pedagogical backdrop that guides the implementation of IBL, in which learners co-construct knowledge through direct manipulation of resources as mediators of learning. The aim is to produce learners who can use their scientific knowledge to solve real-world problems. The CA, with its emphasis on what learners are capable of, shifts the focus from the teacher to the learners as active participants in their own learning, capable of thinking critically and making informed choices. These are central aspects of IBL, in which learners are scaffolded to achieve increasing levels of independence in scientific inquiry.

The CA also recognises that learners' achievement is shaped by social and institutional conditions and experience. This is of particular interest in the current study, which is interested in the contextual factors that enable and constrain the implementation of IBL. The CA highlights that even in the midst of socio-economic constraints, teachers are capable of designing IBL experiences that enhance scientific understanding. There are many ways to mitigate constraints in the pursuit of IBL, such as technology integration and improvisation, which promote equal access to education.

3. Methodology
This section outlines the research design, methodology, and procedures employed to investigate teachers' understanding and implementation of IBL.

3.1 Background
This study explored conceptions and implementation of IBL among Life Sciences teachers. Thus, the study is underpinned by the interpretivism paradigm, as it sought to interpret and make meaning of teachers' experiences with IBL (Creswell & Creswell, 2023). The study adopted a qualitative approach, since it aimed to gather rich data to fully understand the experience of participants about a particular phenomenon (Cohen et al., 2018). Within the qualitative approach, the research adopted a case study design to delve deeply into the lived experiences and practices of teachers regarding IBL.

The type of case study used in this research was the multiple case study, involving teachers in several schools in the King Cetshwayo district. This type of case study allowed the researcher to compare and analyse data relating to each participant before conducting a comprehensive analysis of all the participant cases (Venkatesh et al., 2024). Multiple-case comparison was essential to identify similarities and differences and to spot trends that might not have been identified from the study of a single case.

3.2 Participants
The study was conducted with 10 Life Sciences teachers in disadvantaged public schools. The relatively small sample size is consistent with the interpretivist paradigm and qualitative case study design, where the emphasis is on obtaining rich, in-depth, and contextually grounded data rather than statistical generalisation (Creswell & Creswell, 2023; Cohen et al., 2018). Thus, the selection

of participants was purposive and convenient. Purposive sampling was appropriate because teachers needed to possess specific characteristics to participate in the study (Cohen et al., 2018). The school categories needed for participation were Quintiles 1 and 2, the poorest of five quintiles used to categorize schools in South Africa. All the participants taught Grade 10, and all had administered one or more practical investigations. Sampling was also determined by time and cost efficiency; selecting schools within close range of the researcher and each other ensured sufficient time to interact with all the participants. The data was collected in April and May 2025. Table 1 presents the biographical details of the participants in this study.

Table 1: Biographical details of the participants

Teacher	Gender	Age	Years of teaching experience	Highest qualification
T1	M	41	13	B.Ed.
T2	F	57	31	Teaching diploma
T3	F	39	10	PGCE
T4	F	27	1	B.Ed.
T5	F	33	10	B.Ed.
T6	F	55	25	B.Ed.
T7	F	43	4	B.Ed.
T8	F	26	5	PGCE
T9	F	54	30+	M.Ed.
T10	F	56	30	Teaching diploma

Note: B.Ed.: Bachelor of Education, PGCE: Post Graduate Certificate in Education, M.Ed.: Master of Education

3.3 Instruments and Procedure

Consistent with previous studies on IBL, the study used document analysis, a semi-structured questionnaire, and semi-structured interviews to collect data. Document analysis formed the first stage of data collection and aimed to establish the learners' current levels of inquiry. It focused on the content of a practical investigation that the participants had undertaken. For this, the researcher made use of an analytical rubric derived from the Life Sciences CAPS document, which lists various science-related skills and learner actions as assessment criteria (DBE, 2011). In the second phase, the researcher gave the participants a semi-structured questionnaire to elicit their understanding of IBL in relation to their qualifications and years of teaching experience. The questionnaire comprised 10 semi-structured questions and took about 10 minutes to complete.

The final phase of data collection was the semi-structured interviews, with questions based on the constructs of the CA framework; i.e., resources, functionings, conversion factors and utility. The interviews sought a broader understanding of teachers' conceptions and implementation of IBL in their respective schools. Under resources, the questions sought to establish the availability of interventions, laboratories, and digital equipment in the schools. Under conversion factors, the researcher was interested in the schools' economic and environmental conditions, social influences, and teacher agency, which would have an impact on learners' abilities to convert resources into knowledge.

Under functionings, questions explored the enacted pedagogies, management of inquiry activities within time constraints, and learner performance. Lastly, under utilities, questions examined teachers' perceptions of learners' scientific skills development. The interviews were piloted with Life Sciences and Physical Sciences colleagues in order to detect unclear questions. As a result of the pilot phase, some questions were reworded and the total number of questions was reduced to ensure that the interviews could be completed in under 30 minutes. The design of interviews based on the principles of the CA, helped to yield a holistic understanding of participants' practices.

3.4 Data Analysis

The CA provided the basis for systematic data analysis, with deductive and inductive coding used to categorize data from the documents, the questionnaires and the interviews. Data were categorized under the four themes based on CA tenets of resources, functionings, conversion factors and utility, which enabled a systematic analysis of the ways in which teachers understood and implemented IBL within their contexts. Following Braun and Clarke's (2006) approach, the researcher first familiarized himself with the data, after which codes were developed to categorize participants' responses in questionnaires and interviews. The codes were: access to resources; pedagogical knowledge; teacher training; class sizes; demonstration; doing experiments; narration of experiments; policy demands; motivation; digital technologies and curriculum-driven practices.

The coding process was conducted iteratively to ensure accurate representation of emerging themes. The codes were organized and labelled according to the four tenets of the CA to facilitate reporting of results. The final identified themes were constrained capability to implement IBL; partial enactment of IBL; resource constraints; and teacher agency. All statements were reviewed multiple times across data sources to ensure consistency and accuracy. The refinement of these themes was critical for capturing the nuances of participants' practices.

3.5 Ethical Considerations

The study received approval from the relevant research ethics committee. The approval protocol number is HSSRES/00007962/2024. The research aim, process, expectations of participants and possible risks were clearly explained to the participants both verbally and in writing before data collection began, along with the principles of voluntary participation, anonymity, benefits, confidentiality, data storage and report dissemination. All participants gave consent to participate. In keeping with the principles of anonymity and confidentiality, participants were assigned codes (T1–T10) for reporting purposes, with no personal information given that could be linked with the raw data.

3.6 Ensuring Trustworthiness

Steps were taken to ensure credibility, transferability, dependability, and confirmability to enhance research trustworthiness (Cohen et al., 2018). The study used data triangulation in the form of document analysis, questionnaires and interviews to capture rich and varied data. Member checking was also used to strengthen the credibility and confirmability of the findings. In the report, the participants' verbatim quotations are used to support conclusions, lending further credibility to the results. Transferability was ensured by providing a clear account of the context, participants and procedures, which will allow readers to establish whether the findings would be relevant in similar educational contexts.

4. Results and Findings

This section presents the findings of the study, arranged according to the three research objectives: to establish teachers' conceptions of IBL; teachers' implementation of IBL; and factors affecting teachers' implementation of IBL.

4.1 Teachers' Conceptions of Inquiry-based Learning

Eight of the ten Life Sciences teachers agreed that practical investigation is central to IBL. The other two understood IBL to mean that learners draw conclusions about what they have learned in class. Thus, there were significant differences among their conceptions of IBL, as evident in their comments on teacher-led demonstrations, the activation of prior knowledge, learners' problem solving, and the overall learner-centredness of the methodology. Two teachers reported that IBL was "*how you conduct investigations*" (T1) and "*the teachers provide the material and demonstrate how the investigation is done*" (T10). These statements indicate a reliance on teacher-centred methods in which the teacher conducts a demonstration and the learners watch without taking an active role in experimentation. This is a misconception of IBL.

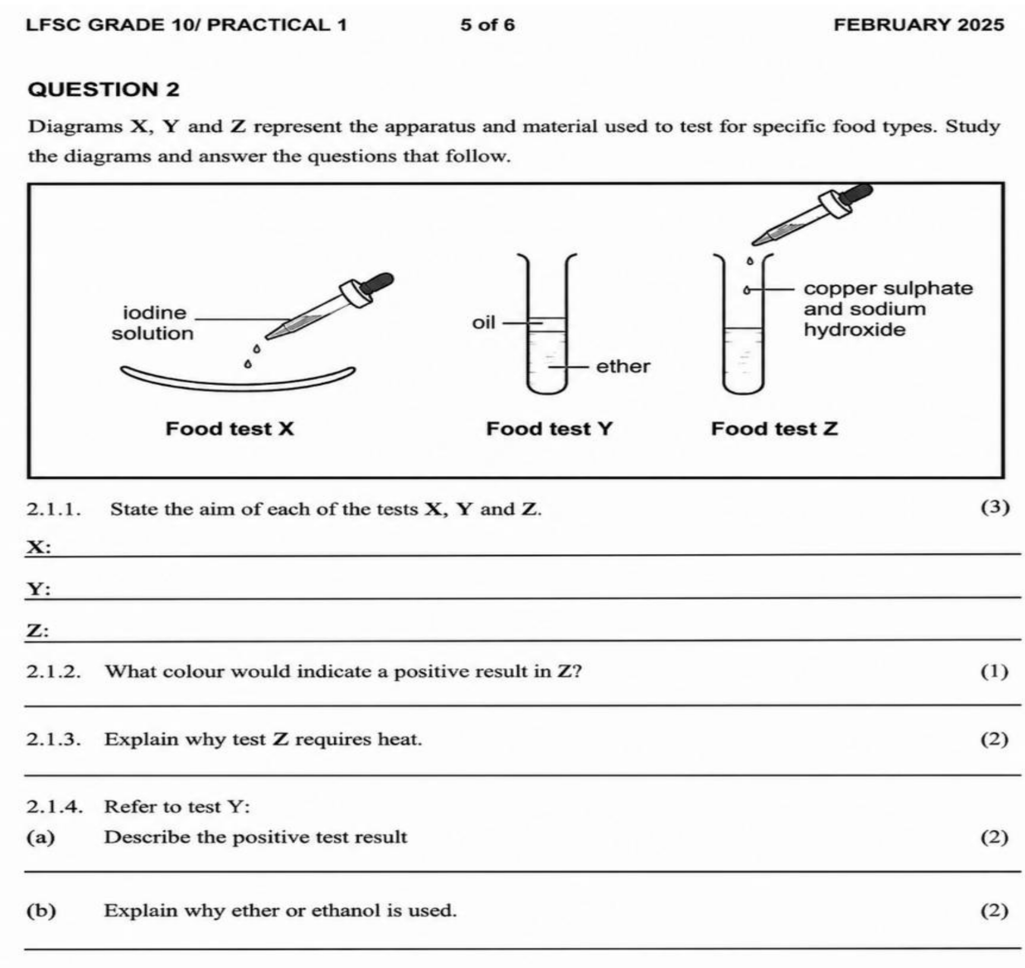
With regard to the activation of prior knowledge, two teachers said, "*Learners can use their knowledge to draw conclusions*" (T2), and "*It is about how much learners know before the topic that would be taught – knowledge of investigations*" (T6). The teachers appeared to conceptualise IBL as an approach that places greater than usual emphasis on learners' prior knowledge. Most understood IBL to involve problem solving. The teachers reported, "*It involves learners in real-world examples through higher order questioning and problem solving*" (T8), and, "*The expectation of the practical is that it must be hands-on and learners must be able to discover information on their own and be able to solve a problem… to enhance the learning experience*" (T4).

Utilising educational technologies to support inquiry-based learning in natural science Another common thread running through teachers' responses in the questionnaire and interviews was the fact that IBL was learner-centred. For example, T8 indicated that "*learners should be able to identify variables and relationships between them "and* T4 reported that "*the practical … must be hands-on*". T8 added that "… *it involves learners in real-world examples*" and T9 said "[it should be] *practically based where learners will be involved*". The teachers clearly conceptualized IBL as a learner-centred approach that involves learners in hands-on activities and in real-world examples rather than being observers or recipients of knowledge.

4.2 Teachers' Implementation of Inquiry-based Learning in Laboratories and Digitalized Contexts

The findings indicated minimal implementation of IBL, with seven Life Sciences teachers still relying on the traditional approach. The other three partially implemented IBL through their use of video-based interactions and open-ended questions. Themes under this topic indicated that teachers had constrained capabilities and only partially enacted IBL. Their ability to use this approach appeared to be determined by contextual factors. For example, some teachers reported that their school did not have a Life Sciences laboratory, while others reported a serious shortage of laboratory equipment.

Teachers said, "*The school does not have glass beakers and chemicals, even though we have the lab*" (T3) and "*We also do not have a laboratory for doing the experiments*" (T6). As a result, the teachers said that they mostly described practical investigations to the learners so that they would be able to answer the exam questions. For example, T5 reported that "*… we just talk about it; we do not do it practically since we do not have the laboratory.*" T4 said something similar: *"Sometimes you need to explain the practical that should be hands-on, that is supposed to be done practically."* Figure 1 shows a class a practical based on a narrated experiment, as extracted from T4's file. The learners were expected to memorize the practical as it was explained by the teachers in order to respond to the questions.



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QUESTION 2

Diagrams **X**, **Y** and **Z** represent the apparatus and material used to test for specific food types. Study the diagrams and answer the questions that follow.

iodine solution

oil

ether

copper sulphate and sodium hydroxide

Food test X

Food test Y

Food test Z

2.1.1. State the aim of each of the tests **X**, **Y** and **Z**. (3)

X: ____

Y: ____

Z: ____

2.1.2. What colour would indicate a positive result in Z? (1)

2.1.3. Explain why test **Z** requires heat. (2)

2.1.4. Refer to test Y:

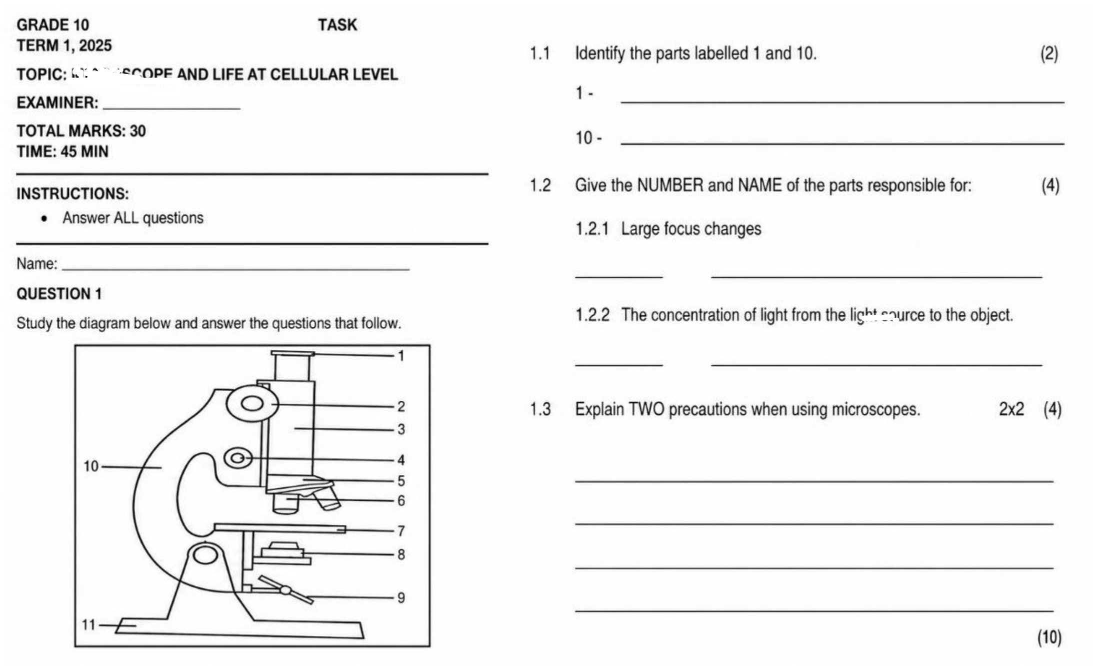
(a) Describe the positive test result (2)

(b) Explain why ether or ethanol is used. (2)

Figure 1: Typical Term 1 practical investigation from Grade 10 teacher's file

Other challenges reported by teachers were time constraints and the pressure of curriculum coverage. They reported that practical investigations took too much time, whereas narrating enabled the learners to answer questions about the experiment during class time. T6 reported that "… *we do it theoretically because* *time is always limited.*" The same comment was given by T8, who also noted the high number of learners. This participant indicated that to conduct experiments, she would have to divide her learners into groups and demonstrate to them at different times, since the laboratory was too small to accommodate everyone at once. This would affect her curriculum coverage. For this reason, she favoured narrating experiments to the whole group.

These reports on time constraints, curriculum coverage and overcrowded classrooms were central to the teachers' inability to implement IBL. Figure 2 shows another example of an exercise based on a verbal description of a microscope, which the learners had not seen in real life. The exercise was extracted from T9's file.



GRADE 10 **TASK**
TERM 1, 2025
TOPIC: [illegible]SCOPE AND LIFE AT CELLULAR LEVEL
EXAMINER: ______________
TOTAL MARKS: 30
TIME: 45 MIN

INSTRUCTIONS:

- Answer ALL questions

Name: ______________________________

QUESTION 1

Study the diagram below and answer the questions that follow.

1.1 Identify the parts labelled 1 and 10. (2)

1 - ______________________

10 - ______________________

1.2 Give the NUMBER and NAME of the parts responsible for: (4)

1.2.1 Large focus changes

________ ______________________

1.2.2 The concentration of light from the lig[illegible]urce to the object.

________ ______________________

1.3 Explain TWO precautions when using microscopes. 2x2 (4)

____

____

____

____

(10)

Figure 2: Typical Term 1 practical investigation from Grade 10 teacher's file

As may be seen, the questions are low-order questions that require only memorization of facts. They do not test scientific skills. Teachers also reported challenges in creating a conducive environment for practical investigations. For example, teachers reported that "*… those [learners] who are ill-disciplined, it is difficult to deal with them*" (T2) and "*We have a challenge of ill-discipline when practical [investigations] are done*" (T6). These quotations suggest that there were some opportunities to conduct investigations, but that they took place in an atmosphere ill-suited to learning.

To overcome some of these difficulties, three teachers reported that they occasionally used digital technologies to augment dysfunctional labs and lack of laboratory equipment. The other seven did not. The three teachers who reported using them said that digital technologies enabled them to implement IBL to a certain extent.

Eight teachers indicated that their schools did not have computers, projectors or internet connectivity to facilitate the integration of technology. Those whose schools had a projector reported not using it. T6, for example said, "*Even though we do have a projector, I have not used it because it takes time to connect.*" This implies that these learners had no opportunity to conduct or watch practical investigations.

The teachers who used digital means indicated that they used their personal laptops or cell phones to show YouTube videos. Occasionally they would pause the video so learners could "*take notes of certain things*" (T3), since they would be expected to answer questions based on the practical they were watching. Lack of data hampered the use of technology. For example, T7 said, "*We do not have internet. If I am using a laptop, I would be using my personal internet and watching certain practicals with my learners.*" T8 said, "*The schools do not have internet. It is the teacher who provides his or her data to assist the learners.*"

In addition, the teachers reported that school policy prohibited the learners from bringing their cell phones to school. When a teacher plans to use a video available on cell phone, he or she would need to write letters informing the parents that cell phones should be brought to school on that day only.

4.3 Factors Affecting Teachers' Implementation of IBL

The findings indicate that all participants felt that their schools did not have sufficient resources for IBL implementation. In addition to the shortage of resources, six teachers felt that they needed workshops to train them in IBL, while four felt that the provision of resources alone would be sufficient.

The three major themes that emerged under this topic were professional development, resource constraints, and teacher agency. According to the participants, they lacked confidence in the use of IBL, which would require targeted training. They mentioned that there were no professional development programmes other than the general orientation programmes presented by subject advisers. T1 indicated that it was easy for him to do practical investigations when he was still at the university, but after his employment as a teacher, these became difficult.

T3 said that she would love to receive training on conducting practical investigations, citing that "*… it has been a long time since doing it*". Professional development was found to be closely related to confidence; T7, for example, said, "*If I can get training on practical before I can give it to my learners …*" and T8 said, "*The training that will assist me with the investigations and the uses of different chemicals.*" These quotes suggest that the teachers were not engaging learners in IBL activities because they felt ill-prepared to do so.

An equally serious challenge was the lack of laboratory resources and digital technology resources, closely related to the socio-economic status of the schools. Neither the schools nor the learners' parents could provide the necessary resources to support IBL implementation. Needed resources included computers, internet connectivity, overhead projectors and cell phones, among others.

Another significant factor was the schools' policies prohibiting the presence of cell phones at school. Finally, quite different findings were made with regard to the teachers' agency. A personal sense of agency enables teachers to convert their own and learners' capabilities into functioning learning environments, even in resource-constrained settings. Some teachers indicated that they used their own data to support learners' inquiry by showing videos on practical investigations, or by demonstrating certain investigations themselves so that learners could at least see the process of science. Although several teachers demonstrated a high level of agency in this regard, their functioning was constrained by the contextual conversion factors of limited laboratory resources. This restricted IBL implementation to low levels of inquiry, preventing opportunities for the learners to develop autonomy.

5. Discussion

This study examined teachers' conceptions and implementation of IBL in laboratories and digitally mediated classrooms. The findings on teachers' conceptions and implementation of IBL and the factors that affect their implementation of this approach are discussed in this section.

The findings reveal that teachers' understanding of IBL is partially aligned with its theoretical principles, in that most knew it was a learner-centred approach useful for developing learner autonomy. Nevertheless, their implementation of it was almost non-existent, as teachers used the traditional teacher-centred approach to teaching. This finding aligns with a study by Shivolo and Mokiwa, (2024), which reported that Namibian teachers' conceptions of IBL were strongly aligned with a book-based style, loaded with memorization.

Similarly, a study on teachers' use of IBL in Indonesia showed a significant lack of understanding of the design elements of IBL (Haris & Mahir, 2025). In contrast, Kazeni and Mkhwanazi (2021) found that teachers in an affluent area of Johannesburg had a well-developed understanding of IBL. Understanding of IBL is unevenly developed and context-dependent, reflecting differences in teachers' abilities to translate theoretical knowledge into meaningful classroom practice. As Kazeni and Mkhwanazi (2021) show, teachers working in more favorable conditions tend to have stronger conceptualisations of IBL than those in less favorable contexts, such as rural schools. This view underscores the role of contextual conversion factors in shaping capability development for IBL.

The findings suggest that in overcrowded and resource-constrained schools, Life Sciences lessons are characterized by teacher demonstrations (where possible) and narration of "the ideal practical". The teachers cited lack of laboratories and associated resources as the reasons for this. Previous studies in South Africa also found that science teachers' practices tended towards the traditional teacher-centred approach (Kunnath & Botes, 2025; Ramnarain & Hlatswayo, 2018). Apart from lack of resources, most teachers indicated that they lacked confidence in the use of the methodology as they had not received training on it. Their inability to implement IBL effectively deprived learners of opportunities to learn through participation and collaboration, a key principle of social constructivism. The barriers highlighted in this study resonate with the findings of previous studies with regard to limited resources, inadequate professional development, and contextual constraints (Akuma & Callaghan, 2019; Ndwandwe, et al, 2025). It was found that classwork exercises were based almost entirely on memorization of teachers' narrations of investigations, rather than learners' own participation in them. As explained by the CA, limited resources act as constraints to the conversion of resources into knowledge. To mitigate these challenges, some teachers used their own digital devices and data, which indicates a measure of teacher agency.

It was unfortunate that in the absence of physical resources, most teachers were unable to make innovative use of digital technologies to simulate IBL. Where laboratories were available, they were under-equipped. Lack of equipment coupled with time pressure meant that, where investigations were conducted, they were undertaken by the teachers and not the learners. This finding echoes several previous studies that found that in the South African context, practical investigations are still confined to conventional laboratories (Akuma & Gaigher, 2023; Nemadziva et al., 2023; Ramnarain & Hlatswayo, 2018). Akuma and Callaghan (2019), for instance, found that interactive computer simulations and virtual laboratories were not accessible to their participants.

Govender and Brás (2025) reported that teachers' self-efficacy and agency are still the main drivers of digital technology use in the classroom. The current study, too, found that teachers who are prepared to use their own devices and data were able to offer an alternative to laboratories. Overall, the findings highlight those socioeconomic constraints, particularly lack of infrastructure such as computers, projectors, smartphones and virtual reality tools, function as conversion barriers and limit teachers' use of digital technologies to facilitate IBL. As a result, teachers are restricted to conventional laboratories, where these exist, as reported by previous studies in South Africa (Akuma & Gaigher, 2023; Nemadziva et al., 2023; Ramnarain & Hlatswayo, 2018). However, despite the challenges, teachers' agency and self-efficacy were evident, as some teachers went the extra mile by using their personal laptops and data to partially enact IBL.

From a CA perspective, a complex interplay of personal, social, and environmental factors constrained the implementation of IBL. Teachers reported limited access to laboratory and digital resources, which restricted their ability to enact IBL. They also expressed low confidence in conducting practical investigations. This was a personal constraint that persisted even where some resources were available. This indicated limited capability resulting from insufficient training. Social and environmental constraints are further shaped classroom practice. Teachers worked in under-resourced schools with poor infrastructure and struggled with overcrowded classrooms and learner discipline.

These conditions made classroom organization difficult and discouraged IBL implementation. The findings showed that improved resource provision could transform constraints into enablers, if teachers simultaneously received adequate training in IBL. Resources could expand teachers' choices and support effective functioning. The study therefore demonstrated that professional development alone is insufficient. Systemic support, including infrastructure and resources, remains essential. The findings carry important implications. Effective IBL implementation requires integrated interventions that address personal, social, and environmental dimensions simultaneously. Sustained, practice-oriented professional development can strengthen teachers' confidence and competence. However, the study suggests the need for targeted professional development workshops by experts, not by subject advisers. Teachers also need context-responsive pedagogical strategies, including cooperative learning, which would help with classroom management.

At the policy level, investment should prioritize both conventional laboratories and digital technologies. Equitable resource allocation is critical, especially in overcrowded and resource-constrained contexts. The schools' governing bodies should draft flexible policies that allow the use of cell phones in curriculum delivery. The findings extend the CA by showing that teacher agency and confidence mediate the conversion of resources into practice. The study also highlights the need for alignment between curriculum expectations and classroom realities. Curriculum guidelines should include flexible and improvised approaches, such as the use of digital tools and alternative resources where laboratories are not available. Clear examples of different inquiry levels should support implementation, as underscored by social constructivism (Moemeke et al., 2025).

The study has limitations. It relied mainly on self-reported data, which may have introduced bias. However, triangulation was used to strengthen the design. In addition, interviews, questionnaires, and document analysis were considered adequate for understanding teachers' conceptions and reported practices. Observations, while valuable, may not have revealed the intentions, reasoning, or contextual challenges influencing teachers' practices. Future research should incorporate classroom observations to validate reported practices. Longitudinal studies should examine how teachers implement IBL over time. Such approaches could provide deeper insight into practices and contextual challenges.

6. Conclusion

This study demonstrates that Life Sciences teachers' conceptions of IBL are only partially aligned with its theoretical foundations, resulting in predominantly teacher-centred practices. From the CA perspective, teachers limited pedagogical understanding and lack of confidence restrict their ability to convert available resources into meaningful inquiry-oriented teaching. Although laboratory and digital resources were recognised as valuable, their scarcity and unequal distribution, shaped by school socioeconomic contexts, significantly constrained teachers' functioning in IBL implementation. Where digital technologies were present, limited access and non-interactive use further curtailed their pedagogical value. Contextual conditions such as overcrowded classrooms and poor learner discipline emerged as key conversion factors that diminished teachers' freedom to enact IBL.

Collectively, these findings illustrate the dynamic interaction between personal, social, and environmental factors in shaping teachers' capabilities. Strengthening IBL implementation, therefore, requires expanding teachers' capabilities through targeted professional development, improved classroom conditions, and equitable resource provision. Aligning these capability-enhancing conditions could transform IBL from a constrained obligation into a viable and empowering pedagogical choice.

This study makes a unique contribution by applying the CA to reveal how teacher knowledge, agency, and contextual constraints shape the enactment of IBL, thereby offering a holistic framework for both theoretical advancement and practical intervention in under-resourced educational contexts. The findings have implications for science education, highlighting the need for equal access and meaningful learner participation, irrespective of context. IBL is an essential component of science education, and every effort should be made to empower teachers to use it.

Conflict of Interest

There were no conflicts of interest in this study.

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