CASE STUDIES OF INQUIRY-BASED INSTRUCTION IN LIFE SCIENCES CLASSROOMS OF SELECTED HIGH SCHOOLS IN STANDERTON

by

LUCKY ERNEST NCALA

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Supervisor: Dr M. Tsakeni

Co-supervisor: Dr T. Jita

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DECLARATION

I, Lucky Ernest Ncala, declare that the thesis, Case studies of inquiry-based instruction in life sciences classrooms of selected high schools in Standerton, submitted for the qualification of the Master of Education at the University of the Free State, is my own, independent work.

All the references I used have been indicated and acknowledged by means of complete citations.

I furthermore declare that this work has not previously been submitted by me at another university or faculty for the purpose of obtaining a qualification.

19 October 2020

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SIGNED   Date

ABSTRACT

Amidst calls for teachers to incorporate inquiry-based instruction in the teaching of science subjects, this study sought to explore how inquiry-based science education is practiced in life sciences classrooms, since there is uncertainty about the efficacy of the professional development of life sciences teachers to practice inquiry-based instruction. Utilising a social constructivist lens, a case study research design and a qualitative research approach, the study explored inquiry-based learning (IBL) practices in life sciences classes. Purposive sampling was utilised to select participants, to ensure that only life sciences teachers who practice inquiry-based instruction participated. Data collection was done with semi-structured interviews that were audio-recorded, and non-participant lesson observations. Data that were generated were analysed with thematic data analysis. Findings were categorised into three themes that had been predetermined according to the three secondary research questions of the study. The themes are teacher perceptions of IBL, strands of IBL used by teachers, and contextual factors that influence the implementation of IBL in life sciences classrooms. Though life sciences teachers have different perceptions of IBL, four overarching perceptions were identified: IBL allows for creative thinking; generates interest in life sciences; ensures active involvement by learners in lessons and promotes interactive learning. Furthermore, findings reveal that the participant teachers practised IBL according to the principles of structured inquiry. Lastly, various contextual factors were identified as having an impact on the participant teachers' practices of IBL in their life sciences lessons. During data generation, the factors were classified as school settings, policies and professional development.

Keywords: Inquiry; contextual settings; teacher professional development; scaffolded inquiry; structured inquiry; guided inquiry; social constructivism; life sciences

DEDICATION

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LIST OF ACRONYMS AND ABBREVIATIONS

B.Com.	Bachelor of commerce
BSc	Bachelor of sciences
CAPS	Curriculum and assessment policy statement
DBE	Department of basic education
DNA	Deoxyribonucleic acid
FET	Further education and training
GTA	Graduate teaching assistance
HOD	Head of department
IBL	Inquiry-based learning
NOS	Nature of science
PGCE	Postgraduate certificate in education
PISA	Programme of international student assessment
ZPD	Zone of proximal development

CHAPTER 1: INTRODUCTION AND BACKGROUND

1.1. INTRODUCTION

This study explored the practice of inquiry-based learning (IBL) in the teaching of life sciences. Wood (2009) and Almroth (2015) refer to a revolution in the teaching of science in general, and life sciences in particular. They argue that this revolution promotes inquiry-based science education as an approach to the teaching of science subjects. Inquiry-based science education is “an instructional learner-centred approach that uses inquiry to integrate theory and practice and develop knowledge and skills to find solutions for a defined problem” (Trna, Trnova & Sibor, 2012:167).

The strain of inquiry-based science approach that framed this study is guided inquiry, as proposed by Kuhlthau, Caspari and Maniotes (2007), who explain that guided inquiry is characterised by a constant engagement of the teacher in guiding learners during inquiry-based practical work, which helps to save time and reduce the learners’ frustrations. Inquiry-based science teaching, of science in general and of life sciences in particular, is hailed as being effective when it is administered as a characterised by teacher guidance offered to learners (Almuntasheri & Gillies, 2010). The concept of scaffolded inquiry is used in the study to accommodate the use of a rubric that characterises inquiry as confirmatory inquiry and structured inquiry as they also involve the presence of the teacher to support and assist learners during inquiry-inclined activities. The concept of scaffolded inquiry is also deliberately applied to use the rubric to determine the levels of inquiry practised by the teachers in the study.

1.2. BACKGROUND

IBL has been adopted as a teaching strategy that is effective in the teaching of science subjects, including life sciences. Almroth (2015:168) defines IBL as “an educational strategy in which learners follow methods and practices similar to those of professional scientists in order to construct knowledge”. Furthermore, IBL is characterised by authentic inquiry activities, wherein learners design and carry out experiments of varying complexity, formulate and test models, and analyse and interpret their own rich data and results (Almroth, 2015).

Using inquiry-based laboratory work in the teaching of science can create a learning environment that encourages learners to question; thereby fostering critical thinking (Almroth, 2015). Furthermore, inquiry-based practical work in science education is advantageous, because it stimulates the conceptual understanding of subject matter, scientific reasoning skills and laboratory manipulative skills and promotes understanding of natural sciences research; this means life sciences teaching through IBL is not only good for fostering experiment-based knowledge, but also for the subject content in its entirety (Almroth, 2015).

Inquiry into the teaching of science is defined by the National Science Education Standards (1995, in Wenning, 2004) as the activities of learners in which they develop knowledge and understanding of scientific ideas, as well as how scientists study the natural world. Haury (1993) introduces and describes inquiry-oriented science instruction as being characterised by active learner involvement, hands-on activities and a discovery approach, which underlies the scientific method. Underpinning inquiry-based science education is the notion that learners should be stimulated to construct their own meaningful knowledge, and by the statement that, “upon entering a science classroom, one should be able to observe an exciting learning environment in which learners are wondering why and finding out; learners should be asking questions, resolving discrepancies, figuring out patterns, representing ideas, discussing information, and solving problems” (Chiappetta, 2015:24).

Wood (2003:113) suggests that life sciences departments should advocate for change in the teaching of the subject towards “inquiry-based teaching across a broad spectrum of research-related experiences, ranging from student-centred, inquiry-based introductory courses to project laboratories to faculty-mentored independent research”. The statement implies a drastic change in the training of life sciences teachers, to becoming experts in the application of IBL within their subject, which resonates with

John Dewey's statement, "learning is based on discovery and mentoring rather than on the transmission of information" (Wood, 2003:113).

Waters (2012) compares the effectiveness of inquiry-based experiments in a laboratory to the 'cook-book' kind of experimentation. Inquiry-based laboratory exercises enable learners to take ownership of laboratory exercises; learners "experience the scientific method and acquire an appreciation and understanding for scientific achievement", and become interested in on-going and future scientific achievements as they relate to current events (Waters, 2012:114).

Hughes and Ellefson (2013) reflect on a study that was undertaken in the United States, wherein the graduate teaching assistants in life sciences were given five hours of training in inquiry-based teaching. The study involved two groups, and the control group was subjected to traditional training that did not follow inquiry-based principles. The results showed a discrepancy between the effectiveness of the two groups' teaching of life sciences, with the experimental group showing greater effectiveness. The results suggest that "offering inquiry-oriented pedagogy graduate teaching assistance training can yield gains in academic performance in undergraduate science labs and improve graduate teaching assistants' teaching of life sciences" (Hughes & Ellefson, 2013:43).

Studies such as that of O'Sullivan (2012) indicate that inquiry-based life sciences teaching enhances learner achievement and helps elicit a high level of enthusiasm, as well as evoke interest by life sciences learners. Findings indicate that learners gained more comprehensive knowledge of life sciences principles they studied when they conducted their own learning and designed their own experiments, which are the key characteristics of inquiry-based science education (O'Sullivan, 2012). These findings confirm that IBL is possibly a pedagogical approach that can improve learner performance in life sciences.

Timmerman, Strickland and Carstensen (2016) report on a pragmatic investigation into the efficacy of inquiry-based curriculum reforms, which were compared to traditional laboratory activities undertaken in the introductory life sciences course for majors at a large state university in south eastern United States. The findings of the study corroborate that of other studies that were undertaken by researchers in the field of inquiry-based science education. Learners showed a great deal of improvement in their academic achievement in life sciences (Hughes & Ellefson, 2013; O'Sullivan, 2012). However, the authors distinguish between concrete topics, such as anatomy, and abstract topics, such as evolution, arguing that inquiry-based sciences education proved to be more effective and yielded positive results for the abstract topics (Timmerman *et al.*, 2016).

1.3. PROBLEM STATEMENT

Chiappetta (2015) describes the nature of the situation in which inquiry-based science education should take place, stating that the classroom should be attractive and stimulate a desire in learners to learn life sciences. Aydin (2016) posits that implementing IBL for teaching life sciences has improved the effectiveness of the teaching of life sciences. His statement resonates with findings reported by literature that report that inquiry pedagogy yields a high degree of learner achievement (Hughes & Ellefson, 2012; O'Sullivan, 2013; Timmerman *et al.*, 2016).

Inquiry-based science teaching has been adopted by African states such as Rwanda (Leon, 2012). Leon (2012) reports that, even though some life sciences teachers in Rwanda have shown an appreciation for the inquiry-based approach to teaching life sciences, most teachers still find it difficult to practice the approach. Like most other "African states, contextual factors, such as lack of resources, overcrowded classrooms and teachers' lack of confidence, hinder the implementation of inquiry-based science teaching" (Leon, 2012:113).

Similarly, despite evidence of efficacy and applicability of inquiry-based teaching in life sciences, South Africa's life sciences teachers are unsure about the approach, and are not adequately trained in the implementation of inquiry-based learning (Ramnarian & Hlatshwayo, 2018). Mogofe and Kibirige (2014) indicate that teachers who are qualified to teach life sciences are uncertain about conducting inquiry-based practical work, which is reflected in the poor performance of learners of life sciences. Furthermore, they argue that teacher training in this regard cannot be confirmed, as the teachers are unable to translate their training into practice (Mogofe & Kibirige, 2014). Despite IBL being embraced as a powerful tool in the teaching of life sciences, South Africa lags behind with its implementation. Research in Mpumalanga province reveals that teachers are positive about the effectiveness of inquiry-based science teaching, but its implementation remains a challenge, as educators do not know how to implement the approach effectively (Ramnarian & Hlatshwayo, 2018).

Teachers' uncertainty and the shortage of adequate teacher training are indicators that the practice of IBL for teaching life sciences faces challenges. Life sciences teachers should receive sound training in how they should implement IBL. Furthermore, the teachers need to elevate their level of confidence and assurance regarding their efficacy of implementing IBL successfully. Therefore, this study was mainly aimed at exploring how IBL is implemented to teach life sciences, with the objectives of exploring the life sciences teachers' perceptions of IBL, the strands of IBL they are using to teach life sciences, and the contextual factors that influence its practice in the classroom.

1.4. RESEARCH QUESTIONS AND OBJECTIVES

1.4.1 Main research question

The main research question of this study was the following:

> How is inquiry-based learning practised in life sciences classrooms?

1.4.2 Secondary research questions

1. How do life sciences teachers perceive the use of IBL in life sciences classrooms?
2. What strands of inquiry are currently practiced in the teaching of life sciences?
3. How do contextual factors influence the practice of IBL in the teaching of life sciences?

The aim of the study was to find out how inquiry-based life sciences teaching is practised at three selected high schools in Standerton.

The objectives of the study were,

1. To find out what life sciences teachers' perceptions about IBL are;
2. To explore the strands of inquiry practiced by life sciences teachers in the three selected schools; and
3. To explore the contextual factors that influence the implementation of IBL in life sciences classrooms.

The main aim of this study was to find out how inquiry-based life sciences teaching is practiced at three selected high schools in Standerton. Delclaux and Saltiel (2013) describe an inquiry-driven lesson as one that is characterised by learner engagement in the discovery of learning, in which learners are actively involved in the experimentation process and the lesson is entirely learner centred. Learning does not only involve the teacher doing or demonstrating to the learners how the problem has to be solved (Delclaux & Saltiel, 2016).

The first objective of the study was to find out what teachers' perceptions about inquiry-based learning are. Adofo (2017) presents findings of a study in which both the teachers and learners enjoyed and found inquiry-based science education in life sciences more effective than any other teaching approach. The efficacy of the teachers in the implementation of an inquiry-based teaching approach depends on the teachers' perceptions (Adofo, 2017). Furthermore, a Turkish study by Bostan (2015:614) indicates that life sciences "teachers' beliefs and perceptions about inquiry-based science education play an important role in the successful implementation of the approach". Teachers play an important role in the implementation and practice of any given teaching approach; therefore, life sciences teachers play a pivotal role in the implementation of an inquiry-based approach to the teaching of sciences.

Furthermore, one of the key objectives of the study was to explore the factors, mostly contextual, which directly and indirectly influence the implementation of inquiry-based education in life sciences. Tsakeni (2018) states that science education in South Africa is influenced by contextual factors, as some schools are better equipped than others for the teaching of science because of the historical political background of the country. It is necessary that educators have sound knowledge about the inquiry-based approach, so that they can be clear about which strain of inquiry they have to use in their teaching. Therefore, another objective was to find out which types of the inquiry-based approach are mostly applied by life sciences teachers in Standerton.

1.5. RATIONALE OF THE STUDY

This study was motivated by personal, career and professional reasons. Personal and professional growth are inevitable, given the fact that I have been working actively as a life sciences teacher since 2009 across the Further Education and Training (FET) phase. In order to broaden my career-growth opportunities, I decided to engage in this research-based study to expand my knowledge of the topic. Logically, due to the expected growth in my knowledge, I expected that my practice as a life sciences teacher would be enhanced by this study.

Research has proven that inquiry-based science education is at the heart of the improvement needed by the teaching of life sciences. This is reflected in the work of Aydin (2016), who postulates that, during the 1990s, teaching life sciences through inquiry improved learners' critical thinking and communication skills and motivated them to learn the subject. Other, similar studies reveal the efficacy of inquiry-based education for the teaching of life sciences, such as in the work of Wood (2012), who singles out IBL, for the improvement of life sciences teaching.

In light of the research findings mentioned above, in this study, I endeavoured to interrogate how inquiry-based education is implemented in the context of South African schools. During a preliminary literature review I discovered that very little has been said about IBL, particularly regarding the teaching of life sciences in the context of South Africa.

1.6. SIGNIFICANCE OF THE STUDY

This study is expected to lead to insight on teacher practices with regard to life sciences inquiry-inclined teaching in the South African context, in particular. Ramnarian and Hlatshwayo (2018) recently undertook a study that reveals that inquiry-based science education has been accepted by some teachers. However, they also indicate that there is still some degree of uncertainty regarding the efficacy and readiness of the teachers themselves to implement IBL, because they are not well trained in the application of inquiry-based instruction (Ramnarian & Hlatshwayo, 2018).

It was envisaged that scrutinising the implementation of IBL by this study would elicit valuable and significant knowledge about the key features of IBL, specifically regarding the teaching of life sciences, which is the most neglected science subject in terms of contemporary literature (Arbie, 2015). This study is anticipated to elicit insights on how life sciences IBL pedagogical approaches are practiced, since most similar studies in the South African context have been largely focused on physical sciences.

1.7. THEORETICAL FRAMEWORK

Social constructivism is the theoretical framework that guided this study. Alanazi (2016) gives a brief account of the constructivist theory of learning, which is characterised by the notion that learners construct their own learning and knowledge through their experiences as they interact with the world. Literature indicates that the constructivist perspective corroborates that IBL is suitable for teaching science. Applefied (2000:41) advocates that, “despite the differences amongst the supporters of constructivism, there is an important congruence among the constructivists with regard to the four central characteristics of constructivism, namely, 1) learners construct their own learning; 2) new learning is dependent on learners’ existing understanding; 3) social interaction plays a critical role; and 4) authentic learning tasks are essential for authentic learning”.

According to Jones and Araje (2002), social constructivism is characterised by a belief that “the child develops knowledge through contacts and interactions with people and then later the child assimilates and internalizes this knowledge adding own personal value to it". Central to the theory of social constructivism is that "learning involves both the teacher and the learner, who both take important parts in the learning process" (Jones & Araje, 2002). Jones and Araje (2002) identify three forms of teaching that follow the social constructivist approach, namely, reciprocal teaching, which involves interactive dialogues between the teacher and learners, followed by turn-taking between the teacher and the learners; peer collaboration, where learners work cooperatively on tasks; and apprenticeship programmes of institutions such as schools, which give learners opportunities to work with experts from various fields (Jones & Araje, 2002).

Grant and Templet (2017) define social constructivism as a method of teaching that emphasises collaboration and social interaction. They emphasise that Lev Vygotsky, who is considered the father of social constructivism, indicates that a learner cannot learn independently, but that the best learning takes place when there is constant social interaction between learners and an instructor or peer who is more knowledgeable (Grant & Templet, 2017). Grant and Templet (2017:68) argue that social constructivism has many components, among which there is the "zone of proximal development, which is described as a zone where learning occurs when a child is helped by others to learn a concept in the class". Social constructivism is suitable for inquiry-based science education and Grant and Templet (2017) postulate that a good social constructivist facilitator is one who will help learners construct knowledge by asking questions.

Amineh and Asl (2015:11), in an account of what social constructivism is, point out that "knowledge and understandings of the world are developed jointly by individuals". Vygotsky (1978) in (Amineh & Asl, 2015) argues that cognitive growth and development occur at a social level and then within the individual, which necessitates constant interaction and collaboration between individuals. Other scholars, such as Ernest (1999), Gredler (1997) and Prawat and Floden (1994) concur that knowledge is socially constructed; they emphasise the role played by social and cultural interaction, which results in effective learning. However, it is important to note that learners' learning during the social interaction is largely dependent upon their social and cultural backgrounds (Amineh & Asl, 2015).

In light of the brief account of social constructivism in this section, I conclude that there is congruence between this theory of learning and inquiry-based learning. Both involve the notion that learning takes place best under circumstances where the learners are exposed to real-life experiences, so that they can construct their own knowledge. Social constructivism was the theoretical framework of this study, because it has commonalities with the basic tenets of IBL. Social constructivism was, therefore, considered the most relevant theoretical framework for this study.

1.8. CONCEPTUAL FRAMEWORK

The main concept underlying this study is guided inquiry, based on the notion that learners rely on a teacher's guidance when they engage in inquiry activities. However, in this study, the concept scaffolded inquiry was used, to avoid confusion about the meaning of guided inquiry. Rubrics are used to classify inquiry, and guided inquiry is one of the strands on the scale. According to Cheung (2008:114), inquiry can be facilitated for learners as "confirmatory inquiry, structured inquiry, guided inquiry and open inquiry". Hansen (2002:35) defines scaffolded inquiry as a type of instruction wherein "the teacher helps the learners develop inquiry investigations in the classroom". Furthermore, the learners advise the teacher on the way to proceed with the investigation (Hansen, 2002).

The conceptual framework guiding this study is based on the approach outlined by Friedler, Nachmias and Linn (1990). Findings in Kuhlthau *et al.* (2007) emphasise the role a teacher's guidance plays during the inquiry process. Learners need intensive guidance and intervention throughout the process of inquiry to elicit a depth of learning and personal understanding, (Kuhlthau *et al.*, 2007). Furthermore, the works of Kuhlthau *et al.* (2007) and Hansen (2002) reveal the significance of creating a third space for the learner, which means what the learner knows about the world, and the curriculum content overlaps to create meaningful learning. The approach by Friedler *et al.* (1990) follows the following steps.

- The learners, under the guidance of the teacher, **identify and define** a scientific problem.
- **Orienting and asking questions** involve learners making observations about scientific phenomena they are interested in. The teacher facilitates the process of formulating the questions, which can be investigated by scientific means.
- **Stating a hypothesis** involves the formulation of the relations between variables and is a prediction of the answer to the questions.
- The learners, guided by the teacher, **design and plan an experiment** to test the formulated hypothesis. This is the stage when learners plan how the experiment will be conducted and what apparatus will be used during the investigation.
- **Observation and collection of data** is the following step, where the learners conduct scientific investigations and make observations to reach the necessary conclusions.
- Learners **analyse and interpret data** based on their observations, which lead to confirmation of the hypothesis.
- **Conclusions** are drawn by the learners following the observations they made during their observations during the investigations.
- **Communication** is the final step, whereby the learners communicate their findings to others in open discussions. However, communication also characterises the entire process, since, during all the stages, learners communicate with one another.

1.9. BRIEF RESEARCH METHODOLOGY

The present study was conducted using the lens of interpretivism as the research paradigm. Rehman and Alhathri (2016:55) posit that "researchers are inextricably part of the social reality being researched, which means that they are not detached from the subject they are studying". The statement describes the relevance of interpretivism to the current study, because I used semi-structured interviews and non-participant observation of lessons presented by life sciences teachers – both methods of data collection ensured that I was part of the social reality that was being explored. In the present study, the reality in question was inquiry-based teaching of life sciences by the participant teachers.

Furthermore, scholars who are supporters of interpretivism reiterate that researchers who use an interpretivist lens hold the belief that the phenomenon being studied is seen through the eyes and thoughts of the participants, not the researcher (Kivunja & Kuyini, 2017; Rehman & Alhatri, 2016). This belief is possible, because interpretivism encourages interaction between the researcher and the research participants (Kivunja & Kuyini, 2017). Such interaction was made possible in the present study by the semi-structured interviews and the observation of lesson presentations. The lesson observations were done in the classrooms where life sciences was taught, which are the natural contexts in which IBL practices take place (Rehman & Alhatri, 2016).

The present study generated qualitative data, and interpretivism was a relevant paradigm that helped to generate such data. Rehman and Alhatri (2016:56) state that “interpretive researchers employ methods that generate qualitative data such as various types of interviews, observations, field notes personal notes, documents etc.”.

The study took the form of a case study, as this design was anticipated to yield the desired findings for a study of this nature. Creswell (2007:73) posits that “case study research involves the study of an issue explored through one or more cases within a bounded system”. In this study, Standerton was the case selected, from which life sciences teachers at three high schools were purposively selected, interviewed and observed while they presented lessons. The issue studied in this case was the practice of IBL. The researcher subscribed to the descriptive case study, which is “used to describe an intervention or phenomenon and the real life situation in which it occurred” (Baxter & Jack, 2008:21). A report will be compiled of the events observed during data collection through observing the lessons presented by the life sciences teachers (Noor, 2007).

This study was guided by qualitative research methodology. Goethals, Sorenson and McGregor (2004) define qualitative research as “a form of systematic empirical inquiry into meaning”. In the definition, “*systematic* means planned, ordered and public; *empirical* means grounded in the world of experience and *inquiry into meaning* means that researchers try to understand how others make sense of their experience” (Goethals *et al.*, 2004). Maree (2014) explains that qualitative research provides textual descriptions of how people experience the phenomenon that is being studied. In qualitative research; a phenomenon being investigated is studied within its natural context (Maree, 2014). Qualitative methodology was relevant to the proposed study, as it studied teachers practicing the teaching of life sciences, in classrooms that served as natural contexts of life sciences teaching.

1.10. PARTICIPANTS

1.10.1 Purposive and snowball sampling

Palys (2008) states that purposive sampling means that a researcher’s way of sampling must be tied to the objectives. Maree (2007) explains that purposive sampling, which is used in qualitative and quantitative research, includes settings, incidents, events and activities, in addition to the selection of participants. To gather information that is relevant to the research question, purposive sampling was employed as a sampling method. This sampling technique is explained by Maree (2007:93) as “selecting participants according to preselected criteria relevant to a particular research question”. One teacher was purposively selected for a pilot study, which would help test the efficacy of the data collection instruments [interview schedule and observation protocol]. The teacher worked at an African rural school and he was purposively selected after I was informed by word of mouth during discussions with life sciences teachers in my circuit that he practiced IBL in teaching life sciences. The data generated during the pilot study was included in the data analysis discussed in chapter 4.

The purposive sampling method was the relevant sampling method for this study, as the following criteria were applied. In this study, data were collected from three preselected high schools in Standerton, which is a small town in Mpumalanga province. Three life sciences teachers were purposively selected (a fourth teacher was later selected through snowball sampling, which will be explained below). The participants were life sciences educators from these high schools who taught life sciences across the FET phase. This explanation corroborates the main distinguishing characteristic of purposeful sampling, which is the application of preselected criteria to choose the sample from the population that could lead to the contemplated results.

The snowball sampling method was also used in the study. The initial number of participants selected through purposive sampling was three and a fourth participant was identified in line with the tenets of snowball sampling. Naderifar, Goli and Ghaljaie (2017:3) posit that, "after gaining access to preliminary samples, the samples begin to introduce other people to take part in the research". Furthermore, Parker (2020:3) argues that "the researchers usually start with a small number of initial contacts, who fit the research criteria and are invited to become participants within the research". The method was relevant to the present study, because at least one participant was identified and chosen to be a participant because of a referral by another participant who was part of the initial sample.

1.10.2 Data collection methods

1.10.2.1 Semi-structured interviews

Semi-structured interviews were used as a main data collection method in the proposed study. Mathers, Fox and Hunn (2002) claim that the interview is an important technique that involves verbal communication between the researcher and the participant. The researcher employed semi-structured interviews because it had benefits for the present study, namely that open-ended questions could be used, which allowed both the interviewer and interviewees to discuss certain topics in detail, and allowed the interviewer to probe for more clarity if answers were not clear (Mathers *et al.*, 2002).

Pathak and Intratat (2015) conducted a qualitative study to investigate teacher perceptions of student collaboration. Semi-structured interviews were relevant to the present study, as they are flexible and consistent with small-scale research, and since only four life sciences teachers were interviewed (Pathak & Intratat, 2015:4). Furthermore, semi-structured interviews can only possibly be applied and used when data is collected from a relatively small sample of participants.

1.10.2.2 Observation

Observation was also used in the collection of data. Maree (2014) describes observation as a data collection method that involves the researcher observing the phenomenon under study. The lesson presentations of four life sciences teachers were observed, which was anticipated to elicit high-quality data, since the data would come to the researcher first-hand, as an observer.

1.10.3 Data analysis

1.10.3.1 Thematic data analysis

Thematic data analysis is a method of identifying, analysing and reporting patterns (themes) within data. It minimally organises and describes a data set in (rich) detail (Braun & Clarke, 2006). Braun and Clarke (2006:86) define thematic analysis as “identifying, analysing and reporting patterns (themes) within data”. The data collected by semi-structured interviews and the observation of lessons was analysed thematically, so that it could be organised (Braun & Clarke, 2006).

This study was guided by a qualitative research methodology through an interpretivist lens, which is why thematic data analysis was suitable for analysis of the collected data. The data collected from the four teachers who took part in this study were divided into various categories. The categories were then classified into various themes to produce a sound representation of the information at the end of the study.

Braun and Clarke (2006) explain that thematic data analysis takes place step by step, in six phases, even though there is no conventional way that is universally agreed upon. The following is a summary of the steps that need to be followed by research that applies thematic data analysis.

Phase 1: Familiarise yourself with your data

The phase involves a process in which the researcher immerses in the data that have been collected, which can be through reading, or listening to recordings made during interviews.

Phase 2: Generating initial codes

This phase starts when the researcher has read and become familiar with the data, and has generated an initial list of ideas about what is in the data and what is interesting about it. Codes identify a feature of the data that appears interesting to the analyst, and refer to the "most basic segment, or element, of the raw data of information that can assessed in a meaningful way regarding the phenomenon" (Boyatiz, 1998, in Braun & Clarke, 2006).

Phase 3: Searching for themes

This phase takes place logically "after the data have been coded. It refocuses the analysis at the broader level of themes, rather than codes, and involves sorting the different codes into potential themes, and collating all the identified themes".

Phase 4: Reviewing themes

During this phase, the researcher will know what themes to keep and which are not really themes, and will have to be discarded. Some of the candidate themes will appear not to really be themes; some may collapse into others; and "others may have to be broken down into separate themes. Data within themes should cohere meaningfully, while there should be clear and identifiable distinctions between themes" (Braun & Clarke, 2006:97).

Phase 5: Defining and naming themes

This phase takes place logically after the themes have been reviewed and a thematic map has been established. At this point, the researcher defines and refines the themes that will be presented for the analysis, and analyses the data within them (Braun & Clarke, 2006).

Phase 6: Producing the report

Braun and Clarke (2006:101) argue that “phase 6 begins when you have a set of fully-worked out themes, and involves the final analysis and write-up of the report. The task of the write-up of a thematic analysis, whether it is for publication or for a research assignment or dissertation, is to tell the complicated story of the data in a way that convinces the reader of the merit and validity of the analysis”.

1.10.4 Ethical considerations

1.10.4.1 Harm or risk and mitigation

Participants have to be informed of any harm or risks the project might cause to them. The researcher has to ensure that the participants understand the nature of the study, so that they understand all the possible harm and risks (Maree, 2014). In the present study, participants were assured that they would not be exposed to any risks.

1.10.4.2 Informed consent or assent

Informed consent is the most important principle of ethical considerations, because no participant should feel obliged to participate in a study. The participants should feel that their rights are respected and that they are not obliged to participate. Escobedo, Guerrero, Lujan, Ramirez and Serrano (2007) posit that “informed consent is a vital step to any research project”. The participants should understand the whole project and the risks involved, and it is up to them to decide whether they want to participate. In this study, the participating teachers were given the opportunity to give their written consent before they participated.

1.10.4.3 Confidentiality and anonymity

The life sciences teachers who participated in the study were assured of their right to confidentiality and that anonymity would be upheld. They were, furthermore, ensured that all the data collected would be kept confidential and the names of the participants would not be divulged, to ensure anonymity (Escobedo *et al.*, 2007).

1.10.4.4 Vulnerable participants

Participants who are vulnerable in any way should be ensured of respect and protection. They must be guided through the informed consent principle and ensured of confidentiality. Some participants can be more vulnerable than others. It is, therefore the duty of the researcher to ensure that they are protected (Escobedo *et al.*, 2007).

1.10.4.5 Conflict of interest

The participants in this study were ensured that the study would not interfere with their obligations to the schools where they taught. The interviews would be administered at times convenient for the participants. Considering their duties as teachers, interviews were administered after school, and the lesson observations did not interfere with their teaching.

1.11. LIMITATIONS OF THE STUDY

This study was carried out at three high schools in Standerton, Mpumalanga. The context is characterised by previously disadvantaged schools that are poorly resourced with regard to laboratory equipment. In two of the three schools, classrooms were overcrowded, which might not allow for inquiry-based learning to be implemented properly and effectively. All participating teachers only practise IBL for practical work, and this does not sufficiently translate into what IBL broadly represents.

1.12. DEFINITION OF TERMS

Inquiry-based science education relates to inquiry, by which we mean the way scientists work, and the activities through which learners learn about both scientific concepts and scientific processes (Kotsari & Smyrnaiou, 2017). Science is a "process of discovery that allows one to link isolated facts to a coherent and comprehensive understanding of the natural world" (Kotsari & Smyrnaiou, 2017:16). Inquiry-based science, therefore, means learning and acquiring knowledge through inquiry.

Life sciences is a collective term used for scientific disciplines that study living things (Kotsari & Smyrnaiou, 2017).

1.13. OVERVIEW OF THE DISSERTATION

This study comprises five chapters. Chapter 1 gave an orientation and introduction to the whole study, stated the rationale and purpose of the study, described the background of the South African context, outlined the guiding research questions and concisely defined the concepts used in the study. Chapter 2 will comprise the literature review, wherein various international and national scholarly articles that articulate views on IBL will be reviewed; the chapter will also describe the theoretical framework and conceptual framework that guided the study.

Chapter 3 will focus on giving an explanation and description of the methodology and how the study was conducted. This information will include the way data was collected, how sampling was done and how data was analysed. Chapter 4 will engage with the process of data analysis, and will report on the thematic data analysis that was applied to analyse the collected data. Chapter 5 will summarise and briefly describe the findings based on the data analysed in Chapter 4. It will also present recommendations based on the findings.

CHAPTER 2: REVIEW OF THE LITERATURE

2.1. INTRODUCTI ON

This chapter will discuss the concept of IBL in the context of life sciences teaching. It will explore the teaching of life sciences in general, and how this is achieved through inquiry instruction in particular, it will describe the incorporation of inquiry-based instruction in life sciences classrooms, and outline a brief review of recent literature in this regard.

Life sciences is a subject that is taught in South African high schools in the FET phase. The efficacy of life sciences teachers depends on, among other factors, their choices of instructional methods (Mthethwa-Kunene, Onwub & De Villiers, 2015). According to a comparative study conducted by Umalusi (2008), the Zambian, Ghanaian, Kenyan and South African life sciences curricula are predominantly characterised by instructional methods that are learner-centred, rather than traditional methods that centralise all classroom activity around the teacher. IBL is a learner-centred instructional approach that is popular for the teaching of science subjects in general, and life sciences in particular (Almroth, 2015). This chapter will, therefore, explore the issues and challenges related to the teaching of life sciences and, subsequently, reflect on other studies into the implementation of inquiry-based instruction in life sciences.

2.2. LIFE SCIENCES EDUCATION

Life sciences is one of the prominent science subjects that is taught across the world. The teaching and learning of life sciences is often characterised by a myriad factors that have an enormous impact on its successful instruction. This statement resonates with the discussions in Cimer (2012), Moore (2013) and Anderman, Sinatra and Gray (2012), who point to factors such as outdated textbooks and curricula, and learner difficulties regarding the conceptualisation of life sciences concepts and topics. Furthermore, the teaching of life sciences takes different shapes in various contexts in the world in terms of instructional methods applied by life sciences teachers (Mwanda, Odundo, Midingo &

Mwanda, 2016). Mwanda *et al.* (2016) posit that most life sciences teachers still practice conventional instructional methods, which translates to poor learner achievement in the subject. In light of the brief explanation above, it can be concluded that the instructional methods applied to teaching life sciences, its successful teaching and learning, and learner achievement in the subject, are inextricably linked.

A study conducted in Turkey indicates that life sciences teaching in Europe is characterised by learners experiencing difficulty conceptualising topics such as the endocrine system and hormones, aerobic respiration, cell division, and genes and chromosomes (Cimer, 2011). Moore (2013) postulates that biology [life sciences] education across Europe is faced by a myriad of serious problems and challenges, which affect most of the teachers of the subject. A non-exhaustive list includes "overloaded and outdated curricula, outdated textbooks, insufficient time to cover content, insufficient real practical work, limitation of the scope of biology, the perception of biology as a soft subject, inappropriate pedagogy, lack of encouragement of teacher creativeness, lack of teacher enthusiasm for the subject, lack of continuous teacher training and a lack of student enthusiasm" (Moore, 2013:26).

Among the most salient issues relating to the teaching of science subjects in Europe is that teachers' choice of instructional practices greatly affects the motivational contexts of science classrooms (Anderman *et al.,* 2012). The shift from biology to life sciences in the South African curriculum means that the subject is now viewed as a complete science subject, which implies that challenges pertaining to instructional practices are also applicable to it. Moore (2013) brings another dimension to instructional practices of life sciences teaching in Europe by arguing that "the information explosion happening in biology[life sciences] – driven by 'omics' technologies and new branches of biology – has consequences for research and education and puts more emphasis on the importance of how biology [life sciences] is taught in schools".

In the South African context, a myriad of studies indicate that the teaching of life sciences is not optimal, which is reflected in learner achievement (Crafford & Viljoen, 2013). In a study undertaken at schools in Tshwane north, Crafford and Viljoen

(2013:46) point out that “the South African education fraternity has been hit by a wave of curriculum change, which is conspicuously reflected in the teaching of life sciences”. A change in the curriculum necessitates a change in pedagogical practices in science classes. Despite an emphasis on a shift to learner-centred teaching approaches, Dudu (2015) postulates that the teaching of life sciences at most South African schools is teacher centred and is widely characterised by a lack of practical work, even in instances where it is prescribed. He ascribes this situation to teachers lacking practical skills. Such a practice threatens the efficacy of science teaching.

The life sciences Curriculum and Assessment Policy Statement (CAPS) of the Department of Basic Education (DBE, 2011) states that the teaching of the subject should now be characterised by scientific inquiry, which teachers and learners need to employ in their teaching and learning. The statement indicates that teaching should engage learners actively to maximise learning, rather than implementing the traditional rote learning, where learners are passively involved in lessons. Learners should acquire knowledge and develop skills that will facilitate their transition from the learning environment to the workplace (DBE, 2011). It is, therefore, a prerequisite for life sciences teachers to be acquainted with teaching methods that enable the teaching of science in a way that will assist learners to understand the nature of scientific inquiry.

The teaching of life sciences in the South African context is characterised by various factors, mainly contextual, that influence the efficacy of teaching. Samuel and Dudu (2017) present the findings of a study conducted in the North West province, which involved them observing two life sciences educators teaching in two different contexts. The findings show that the teaching of life sciences depends on “contextual factors, such as classroom environment, learner commitment, the language proficiency of the learners, and the availability of resources” (Samuel & Dudu, 2017:34). Therefore, the teaching of life sciences is characterised and influenced by a myriad of factors that are inextricably linked to one another.

2.3. INQUIRY-BASED LEARNING

In his article about scientific inquiry and inquiry-based life sciences learning, Walker (2007) clearly delineates inquiry-based science teaching and learning. To bolster his description of how IBL operates, Walker provides a clear comparison between inquiry and non-inquiry science teaching and learning. When they do research to construct knowledge, learners are afforded opportunities to work in ways similar to how scientists do. Learners become junior scientists by formulating their own questions, stating hypotheses and, eventually, designing investigations that test the hypotheses, and finding the best answers for their proposed scientific questions (Walker, 2007). It is, therefore, noteworthy that inquiry-based instruction is mainly characterised by learners taking the most active role in the lesson, and the teacher assuming a facilitator role, unlike in the traditional method, where the teacher plays the most active role and the learners are relegated to a passive role.

According to Dagys (2017), IBL has its roots in the work of science teachers who played an active role in researching the patterns of children's learning, which include Jean-Jacques Rousseau (1712-1778) and Pestalozzi (1746-1827). Dagys (2017) reports that these teachers were supporters of constructivism, particularly social constructivism (which will be explained in 2.4). IBL rests on four principles, which are common to all the modern theories of learning:

> *learning takes place through constructive, science-based, knowledge structures; transfer of knowledge is focused on the process, which combines conscious and unconscious perception; the circumstances, when knowledge acquired and subsequently used, have to be set at the beginning of the study period; knowledge is constructed so as to be reliable and sustainable currently and also could be applied in the distant future (Dagys, 2017:92).*

Over time, more teachers became interested in IBL research. One of the most recent forms of IBL has its roots in the work of John Dewey, a former science teacher who viewed activity and experience as important aspects of learning, and encouraged science teachers to employ scientific inquiry, which is a method used by real scientists to discover knowledge in the teaching of science (Dewey, 1910). According to Barrow (2006:266), “Dewey encouraged that learners should be taught in ways that could add to their knowledge of science, by addressing problems that they want to know and apply to observable phenomena”. In essence, this implies that science learners are not only taught science content, but are also afforded an opportunity to develop relevant scientific skills relating to acquiring knowledge, thereby preparing them for the workplace.

Amidst a myriad of definitions of inquiry, Maaß and Artigue (2015:781) define it as

> *a multifaceted activity that involves making observations, posing questions, examining books and other sources of information to see what is already known, planning investigations, reviewing what is already known in light of experimental evidence, using tools to gather and analyse interpret data, proposing answers, explanations and predictions and communicating the results.*

In light of the definition above, it is evident that inquiry is a method used by scientists to construct scientific knowledge. Harlen (2015) claims that using inquiry in teaching science is necessitated by a need to get learners actively involved in learning activities. When inquiry is used as a teaching approach, the teacher allows autonomy for the learners to ask their own questions and conduct investigations to answer the questions. The teacher moves away from being an instructor and adopts the role of a facilitator (Maaß & Artigue, 2015). Chu, Reynolds, Tavares and Lee (2017) define IBL as “a learner-centred approach that uses questioning to actively engage learners in their own learning”.

According to Lederman, Lederman and Antink (2013), “helping learners develop adequate conceptions of nature of science and scientific inquiry has been an ongoing objective in science education and how learners develop scientific knowledge is related to scientific inquiry”. Most education reforms that have taken shape in the teaching of science subjects indicate that educationists advocate scientific inquiry in teaching the subjects, which is a method by which scientists construct knowledge through using approaches that help them answer their questions (Lederman *et al.*, 2013). This implies that utilising IBL to teach science subjects resonates with what scientists do when they construct knowledge, and learners should be guided towards employing the same methods to construct their own knowledge.

Using inquiry as a pedagogical approach not only helps prepare learners for their academic progress, but also makes them aware of the world within which they live; it prepares them for the roles they will play in society (Harlen, 2015). Harlen (2015) and Chiappetta (2016) explain that IBL helps learners to develop science process skills that are used by scientists to construct knowledge about the world around them. Therefore, by engaging in inquiry lessons, learners are prepared to develop scientific ways of constructing knowledge. Furthermore, Harlen (2015) emphasises that inquiry-based science pedagogy should not be used as the only strategy to teach scientific ideas. Instead, teachers should be conversant with other relevant pedagogical strategies.

IBL has three stages, namely, "motivation, knowledge construction and its improvement. This implies that learners should be provided with relevant motivation measures so that they can actively engage in the process of knowledge construction and be afforded opportunities to enhance the knowledge they have constructed" (Dagys, 2017:92). This means that teacher professional development should equip science teachers with the skills necessary to know when to incorporate IBL in their teaching, and the nature of the lessons that are best for using the instructional strategy, to yield the intended results.

2.3.1 Types of inquiry-based learning

The present study discusses four forms of inquiry that can be used for the teaching of science subjects. To distinguish between various levels of inquiry and the extent of the efficacy of each, open inquiry, structured inquiry, guided inquiry and confirmatory inquiry will be discussed briefly in this section. Scaffolded inquiry will be elaborated on in the conceptual framework. In explaining that inquiry manifests in various forms, Artayasa, Susilo, Lestari, Indriwati (2018:237) indicate that inquiry occurs at four levels: “confirmatory inquiry, structured inquiry, guided inquiry and open inquiry”. Furthermore, “the four levels of inquiry are distinguished by the amount of teacher involvement in learning and teacher involvement decreases with the increasing inquiry level” (Artayasa *et al.*, 2018:237). Life sciences teachers should be conversant with the benefits and the shortcomings of each of the forms of inquiry, to enable them to make informed choices regarding how they can implement inquiry in the classroom.

The present study used guided inquiry as a conceptual framework. However, the concept of scaffolded inquiry was applied to accommodate other strands of inquiry that are characterised by the presence of the teacher guiding the learners through inquiry activities and thereby avoid confusion with the meaning of guided inquiry. Furthermore, the concept scaffolded inquiry is used deliberately, so that the rubric describing confirmatory inquiry, structured inquiry and guided inquiry can be used in this study without the meaning of guided inquiry causing confusion (Bell, Smetana & Binns, 2005). Bell *et al*. (2005) present a model that can be used as a rubric to determine the level of inquiry practiced by teachers in the classroom. The level of inquiry is determined by the amount of information given to the learners.

Table 2.1: The four strands of inquiry and the level of scaffolding

Modified version of the four levels of inquiry. How much information is given to the learner?				
		What the teacher provides the learner		
Level of inquiry	Type of inquiry	Question?	Methods?	Solution?
1	Confirmatory inquiry	X	X	X
2	Structured inquiry	X	X	
3	Guided inquiry	X		
4	Open inquiry			

- Confirmatory inquiry is the lowest level of inquiry. The teacher provides learners with the question to be investigated and the methods of gathering data, and guides them towards the expected conclusion.
- In structured inquiry, learners are provided with a question and a method. Learners are responsible for interpreting the results and drawing up a conclusion.
- Guided inquiry involves giving learners a question, and they determine their own method of gathering data. They are responsible for the interpretation of the results and drawing up a conclusion.
- Open inquiry is the highest level of inquiry. Learners take responsibility for all major steps of an investigation.

Botha (2016) is among the scholars who believe that IBL can be implemented at various levels, which largely determine the degree of learner involvement during the inquiry activities. He argues that,

> *IBL can range from a rather structured and guided activity, particularly at lower levels (where the teacher may pose the questions and give guidance on how to solve a problem) to independent research where learners generate the questions and determine how to address and solve them (Botha, 2016:79).*

This chapter incorporates the above proposition into and distinguishes between the four levels of scientific inquiry.

2.3.1.1 Confirmatory inquiry

Zion and Mendelovici (2012) describe confirmatory IBL as being characterised by the teacher developing the questions and methods for the learners. Furthermore, learners are guided through an activity with known results – the aim of the investigation is to confirm the known results rather than to construct new knowledge (Zion & Mendelovici, 2012). This is the lowest level of inquiry, as described in Table 2.1, which shows the levels of inquiry through which teachers can teach science subjects in general, and life sciences in particular.

2.3.1.2 Structured inquiry

Whitworth, Maeng and Bell (2015) describe structured inquiry as the type or level of inquiry where the learners are given the question to be investigated and the procedure to be followed to answer the question, but they are not given the outcome. Bell *et al.* (2005:2) present a similar explanation, by stating that, in structured inquiry, "learners investigate a teacher-presented question through a prescribed procedure". In light of these two explanations, it can be concluded that structured inquiry is characterised by teacher involvement in the inquiry process, because the learners only carry out an investigation through ways that are conventionally stipulated by the teacher. Zion and Mendelovici (2012:391) echo that "the teacher presents a question and the learners investigate it by means of a prescribed procedure; they receive step-by-step guidelines at each stage, leading to a predetermined outcome, which resonates with following a recipe". Furthermore, learners engage with scientific procedures, which stimulates the "development of basic scientific inquiry skills, such as making observations, raising hypotheses, collecting and organising data, drawing conclusions, making inferences and finding solutions" (Zion & Mendelovici, 2012:393). However, learners do not acquire the ability to think autonomously, because, in structured inquiry, learners do not have the opportunity to set their own questions and to generate their own processes through which to seek answers to the questions (Zion & Mendelovici, 2012). In the South African context, physical sciences teachers have been observed using structured inquiry when facilitating inquiry-based practical work (Tsakeni, Vandeyar & Potgieter, 2019).

2.3.1.3 Open inquiry

Pöntinen, Kärkkäinen, Pihlainen and Räty-Zaborszky (2019) state that open inquiry is the most complex level of inquiry, which provides a high degree of autonomy to the learners, who pose their own questions that will guide the inquiry activities. Other researchers share similar conceptions regarding open inquiry, such as Van Uum, Verhoeff and Peeters (2017), who posit that, in open inquiry, learners take charge of their own learning by posing the questions themselves, whereafter they conduct science investigations to generate data to answer the questions autonomously. Teachers do not assume their traditional role of playing the most active role in the lesson. However, teachers are expected to give support to the learners, especially in the early stages of the inquiry process, which Van Uum *et al.* (2017) refer to as scaffolding. Bevins and Price (2016:2) agree by stating that "an over-emphasis on the subject facts reduces the space for thinking and developing attitudes about science, [which] has been discussed and debated within the science education literature over a number of decades". This assertion leaves room for open inquiry, since it affords learners opportunities to develop questions and carry out investigations independently, which are effective for the development of their critical thinking abilities.

Despite the identified benefits of open inquiry, its advocates should be informed that it has certain shortcomings that cause its effectiveness to be questioned by researchers. Bevins and Price (2016) posit that minimally guided forms of inquiry do not work, and learners may take longer to complete tasks, since no guidance is given to them. Artayasa *et al.* (2018) agree, by stating that, even though open inquiry is the highest level of inquiry, not all learners are able to carry out self-directed learning without the teacher's assistance. The argument reflects the shortcoming of open inquiry, which relates to the fact that teachers have a standardised curriculum with content that should be completed within timeframes stipulated by the departments of education.

2.3.2 The benefits of using inquiry-based instruction in science teaching

IBL is a pedagogical approach that is gaining traction, as it shows significant efficacy in the retention of scientific knowledge by learners in all science disciplines. Bevins and Price (2016) outline a number of benefits that can be achieved by practising IBL in science classrooms. They report that IBL enables learners to utilise their current knowledge to construct new knowledge. Furthermore,

> *this approach gives learners better ownership of their learning and allows them to actively navigate the routes to increased understanding, greater motivation, improved attitudes to scientific endeavour and growth in their self-esteem and their ability to handle new data in an increasingly complex world.*

Walker (2007) refers to the benefits outlined by Bevins and Price (2016), and argues that learners who are taught science through inquiry instruction show more interest in and motivation to learn science. IBL can mitigate the general decline in interest in science among learners as they enter and proceed through secondary school. Two other important advantages were identified by Walker (2007). Firstly, learners understand and remember scientific knowledge better when they are taught through inquiry and, secondly, learners learn how scientists generate and construct knowledge and how the existing body of scientific knowledge was developed and produced (Walker, 2007). The last two advantages indicate that inquiry instruction has an added advantage for learners: they not only conceptualise existing scientific knowledge better, they also develop key knowledge discovery skills using the scientific method, thereby preparing them as prospective scientists.

According to Scott, Smith, Chu and Friesen (2018), “the 2015 Programme of International Student Assessment (PISA) results indicate that Singapore, Japan and Estonia have become global leaders in education”. Arguably, the education systems mentioned above use IBL as a pedagogical approach and the results indicate a huge improvement in learner achievement, especially in science subjects (Scott *et al*., 2018). It is, therefore, on the basis of the evidence from the results of this and other studies mentioned in the first chapter of this study that the successful implementation of IBL is advocated to improve the effectiveness of the teaching of science subjects, including life sciences, which is the focus area of the present study.

Batdi, Semerci and Aslan (2018:62) report that IBL “has a positive impact on learners’ attitudes toward course, academic achievement and the degree of retention”. Furthermore, IBL increases learners’ eagerness to display a positive attitude by increasing their interest in the lesson, which means that learners listen and participate actively (Batdi *et al.*, 2018). Learners taught through inquiry show a high level of confidence; they find lessons more enjoyable – a factor that can encourage them to learn and develop sound thinking and processing skills (Batdi *et al.*, 2018).

Ramnarian and Hlatshwayo (2018) point out that IBL has benefits that are well-established by empirical research. They argue that doing inquiry in science subjects instils motivation and stimulates interest in learners, contributes to the development of conceptual understanding in science, and provides insight into the world of the scientist (Ramnarian & Hlatshwayo, 2018). Kuhlthau (2010) posits that, in addition to increased levels of motivation, IBL helps learners to develop social, language and reading skills, because they communicate while working in groups and they engage by reading a variety of sources to gather pertinent data. The activities learners engage in during scientific inquiry afford them opportunities to construct their own learning and they gain independence in research and learning.

Inquiry-based science instruction has been practiced for a long time and research shows that it "enhances student performance, fosters scientific literacy and understanding of science processes, promotes positive attitudes to science, leads to higher achievement on tests of procedural knowledge, and develops communication skills" (Haury, 1993:71). Studies, such as those of Scott *et al.* (2017), present the results of interrogating the effect of IBL in certain courses that are expected to be taken by all students of life sciences at the University of Glasgow. The students showed significant improvement in the grades they attained after the implementation of IBL as a pedagogical method (Scott *et al.*, 2017:11).

2.3.3 Challenges facing the implementation of inquiry-based learning

Scholars of IBL have identified challenges that preclude the implementation of IBL in many parts of the world. Barrow (2006:271) identifies factors such as "limited teacher preparation, lack of time, few available materials, lack of support, emphasis on content only, and emphasis by textbooks on science as a body of knowledge, as the major challenges science teachers face in implementing IBL as a pedagogical approach to the teaching of science subjects, including life sciences". Bevins and Price (2016) assert that "other models of inquiry are too limited, revolve around extensive practical work, and omit the wealth, power and the complexity of the scientific endeavour". Therefore, where teacher training is ambiguous regarding the types of activities and content to be learnt through inquiry, inquiry-based pedagogy is of limited effectiveness.

Angraeni, Supriatno, Nuraeni and Rissa (2016) argue that IBL as a pedagogical method requires considerable professional teacher development to ensure sound knowledge by teachers for successful enactment of IBL. However, most science teachers who possess sound content knowledge of their respective subjects struggle to use IBL as a pedagogical method, since they were not taught through inquiry by their teachers, and are likely to teach the way they were taught (Angraeni *et al.,* 2016). Therefore, literature indicates a gap in the professional development of science teachers to prepare them to implement IBL, which is reflected in their ineffective implementation, or failure to implement the pedagogical method to enhance the teaching of science subjects.

Research shows that both teachers and learners should understand the nature of science and scientific inquiry in order to implement IBL effectively in teaching science subjects. However, there is uncertainty about teacher professional development for teaching science through inquiry-based instruction (Lederman *et al.*, 2013). Papaevripidou, Irakleous and Zacharia (2018) argue that, despite the multiple learning benefits that learners experience when engaged in inquiry-based activities, many science teachers still do not practise IBL due to factors such as the teachers' lack of knowledge of IBL, teachers' preference for direct and teacher-centred approaches, lack of activities in textbooks and lack of skills to implement IBL. These challenges, if not addressed, might result in unsuccessful and ineffective implementation of IBL.

Despite its widely accepted efficacy and the positive effects it has on learning, some scholars still critique and question the implementation of IBL in various contexts. Chu *et al.* (2017) argue that

> *discovery-based approaches are ineffectual, due to a lack of structure in autonomy-supportive inquiry-based learning contexts, and excessive*

cognitive load that can result, which can over-tax the working memory needed to learn the core material.

Furthermore, learners might find it frustrating when they have to find informational resources to use during the inquiry processes (Chu *et al.*, 2017). Lederman *et al.* (2013) posit that the lack of effective professional teacher development in IBL is reflected in learners' challenges relating to successfully learning through inquiry, since learners lack relevant guidance. These challenges, therefore, necessitate high-quality professional development of science teachers to implement IBL effectively.

2.4. THE PRACTICE OF INQUIRY-BASED LEARNING IN TEACHING LIFE SCIENCES

2.4.1 The international landscape

IBL has been adopted by teachers of science subjects, including life sciences, all over the world. A study based on the Baduy society of Indonesia by Saefullah, Samanhudi, Nulkahim and Berlian (2017) found that IBL leads to improvement in learners' acquisition of scientific literacy. It is important that learners master scientific literacy and, in this context, scientific literacy refers to the way learners understand scientific content. Scientific literacy is divided into four major domains: science content, science process, the context of science applications, and attitudes (Saefullah *et al.,* 2017). The results of the study indicate the efficacy of applying IBL in the teaching of science subjects generally, and life sciences in particular, which is one of the science subjects growing in importance in the curricula of education departments across the globe.

2.4.1.1 Implementation of inquiry-based learning in teaching life sciences

IBL is practiced by life sciences teachers all over the world, with research attesting to its efficacy in the teaching of the subject. According to Barral, Ardi-Pastores and Simmons (2017:2), "hands-on, inquiry-based and active learning approaches seem to have a positive impact on student learning and engagement". They refer to the flipped classroom environment approach that is used by life sciences teachers in San-Diego, which creates more time for classroom activity, and using didactic videos to ensure teaching outside classrooms, which is a form of IBL, which has proven to be effective in the teaching of life sciences (Barral *et al.*, 2017:5). The study corroborates the idea that IBL is effective in the teaching of sciences subjects, including life sciences.

2.4.1.2 Teacher perceptions

Life sciences teachers and their perceptions play a significant role in the implementation of IBL in the teaching of the subject, as they are the people who are expected to implement the approach and give proper guidance to learners to maximise and ensure its efficacy. Angraeni *et al*. (2016) argue that some teachers have not been exposed to the teaching of science and life sciences content through inquiry, neither during their own school days nor during their college training. Such teachers, therefore, do not find it useful to use IBL to teach science and life sciences content (Angraeni *et al.,* 2016). It is in the light of this statement that I conclude that the backgrounds of teachers, whether they ever received instruction through inquiry, or not, plays an important role in terms of whether they perceive IBL as a pedagogical approach positively or negatively.

In a study conducted in Finland and South Korea, Kang and Keinonen (2016) found teacher perceptions about IBL in the teaching of science to be crucial. The study reveals that most teachers are still reluctant and have little confidence to use IBL, which leads to them practicing the traditional teacher-centred pedagogy, because they believe that issues such as lack of time and resources, tight curricula, large class sizes and inadequate professional development prevent the implementation of IBL for science teaching (Kang & Keinonen, 2016). A study conducted in China found that teachers have only a moderate knowledge of the nature of science, which is directly attributed to insufficient teacher professional development in inquiry; therefore, they only have moderate knowledge regarding the use of IBL (Xie, 2014). Teachers in these countries generally exhibited a negative attitude to the use of IBL and it may be because of these and other factors, and that they generally perceive IBL to be a pedagogical approach that is not easy to implement.

Ssempala (2017) outlines several science teacher perceptions concerning the use of IBL as a pedagogical method and vehicle to teach science subjects. In a qualitative study he conducted in Uganda, a developing African country, science teachers at two schools perceived IBL to be impossible to implement, because it takes more time, especially when learners in the class have average performance (Ssempala, 2017). Furthermore, teachers are negative and reluctant to switch to using IBL in Uganda, because they believe learners can only do inquiry when they know something about the content they are about to learn, which implies that they cannot be confronted with new content through IBL instruction, because they cannot respond to the questions posed to them (Ssempala, 2017).

2.4.1.3 Teacher professional development

Despite a growing interest amongst educationists in promoting curricula that advocate the teaching of science using IBL, the greatest challenge is that there is no convincing evidence that the teachers have been adequately trained to implement it as a pedagogical method. The major reason why teachers are reluctant to change their way of teaching to IBL seems to be lack of professional development (Van-Diepen Scheerboom, 2017). Van-Diepen Scheerboom (2017) reflects on a study that interrogated the dissemination and implementation of IBL by observing the lessons of three life sciences teachers. The teachers faced challenges relating to allocating time to inquiry lessons; failure to engage learners in class discussions because learners were uncontrollable; frustrations that accompanied lesson preparation; and the teachers' general reluctance to change the way they teach (Van-Diepen Scheerboom, 2017). These challenges are attributed to life sciences teachers being uncertain how to use IBL in their teaching, which was caused by a lack of sound training on how to implement IBL.

Kang and Keinonen (2016:35) point out that "another impediment to implementing IBL is the insufficient and inadequate professional development of inquiry pedagogies for pre-service and in service teachers". Their arguments corroborate Van-Diepen Scheerboom's (2017) study, as they state that the biggest challenge is that teachers tend to teach the way they were taught, and this means using teacher-centred pedagogies that keep the learners divorced from the learning process – relegating them to inactive roles of merely receiving the content that is passed down to them by the teacher, who takes the most active role (Kang & Keinonen, 2016). This situation indicates a global challenge regarding the effective implementation and practice of inquiry-based pedagogies in the teaching of science subjects.

2.4.1.4 Contextual factors

According to the findings of the study conducted in Uganda by Ssempala (2017), the implementation of IBL in African developing countries depends on a myriad of contextual factors, which need to be controlled for IBL to be implemented successfully. The teachers interviewed mentioned lack of motivation, shortage of resources (teaching material), unsuitable modes of assessment, large class sizes, the nature of pre-service and in-service teacher-training, limited time for teaching many lessons, and a great deal of content to cover as the contextual factors affecting the implementation of IBL in Uganda (Ssempala, 2017).

Kang and Keinonen (2016) also report that contextual factors play an integral role in the practice of IBL. They argue that schools in Finland and Korea lack appropriate teaching material, such as science laboratories or digital resources, which negatively affects teachers’ confidence about using inquiry-based pedagogical approaches to teaching science (Kang & Keinonen, 2016). At some schools, teachers were unable to implement IBL successfully, because schools generally lack funding to support and provide the necessary materials to implement IBL (Kang & Keinonen, 2016). It is, therefore, noteworthy that schools need to be supported financially to provide all the necessary teaching materials required to practice IBL.

Substantiating claims about contextual factors, teachers indicated that Ugandan science classes were generally large, which meant that teachers could not attend to individual learner needs; teachers were not motivated because they were not adequately remunerated; the type of assessment was imposed by government and did not suit IBL, as it required the learners to memorise facts; teaching aids were lacking and the teachers were unable to use them for IBL; and teachers who were interviewed showed very little evidence of their pre-service training having incorporated IBL (Ssempala, 2017).

2.4.2 The South African landscape

The South African education system has been subjected to reform, which has been necessitated by the legacies of apartheid policies. Ramnarian (2016) posits that the aftermath of apartheid is reflected largely by the imbalances that exist between schools in various contexts, with schools that were previously meant for whites having adequate physical resources needed for teaching and learning. On the other hand, schools in townships, where most previously disadvantaged blacks reside, lack even basic resources needed for effective teaching and learning (Ramnarian, 2016). With the inception of the new CAPS, the government explicitly shows that the intention is to redress the imbalances brought about by the formerly segregated type of curriculum, by introducing science teaching driven by an inquiry-based approach (DBE, 2011). The implementation of such a curriculum in South Africa is, however, largely influenced by factors that Ramnarian (2016) divides into intrinsic and extrinsic factors.

Ramnarian (2016:602) identifies and classifies factors pertaining to the "lack of professional science knowledge (content knowledge, pedagogical knowledge, knowledge of learners, education contexts, curriculum and education purposes) into intrinsic factors that preclude the effective implementation of IBL in South African schools". Furthermore, he identifies factors such as the availability of physical resources (laboratories and facilities for practical work) and classifies them under extrinsic factors, and explains how schools in different social contexts in South Africa are affected differently by these factors. This section will present and discuss the following factors: teacher professional development, contextual factors and teacher perceptions and beliefs.

2.4.2.1 Teacher professional development

Tsakeni (2014) reflects on the significance of the professional development of teachers she observed executing practical IBL activities. In her study, the participating teachers indicated that they were professionally ready to implement IBL in teaching science subjects. Bautista and Ortega-Ruiz (2015) subscribe to Avalos’s (2011:14) propositions, which define professional development as “being about teachers learning – learning how to learn – and transforming their knowledge into practice for the benefit of their learners’ growth. Teacher professional learning is a complex process, which requires cognitive and emotional involvement of teachers, individually and collectively, the capacity and willingness to examine where each one stands in terms of convictions and beliefs, and perusing and enacting appropriate alternatives for improvement or change”.

According to Kennedy (2016), teacher professional development can improve teaching. Kennedy (2016) gives a similar account as Bautista and Ortega-Ruiz (2015), by arguing that effective professional development is reflected in the efficacy of the teachers’ use of pedagogical approaches and strategies that address learners’ needs.

Dudu (2015) posits that teacher development intervention activities in South Africa do not address the needs of educators and seldom improve the practice of teaching science subjects. His statement corroborates findings of Ramnarian and Hlatshwayo (2018), who argue that one of the significant factors that impede the efficacy of teaching science subjects in South African schools using inquiry-based pedagogy is a lack of teacher professional development. These propositions by these authors indicate that there is no evidence of continuous, relevant, general professional teacher development. Dudu (2014a) points out that curriculum transformation in South Africa has led to the adoption of inquiry-based pedagogy for teaching science subjects. Teacher professional development remains one of many challenges that impede the successful implementation of IBL in teaching science subjects, including life sciences, in South African schools (Dudu, 2014a).

2.4.2.2 Class sizes

According to Marais (2016), overcrowded classrooms remain a challenge in South African schools, and this challenge largely remains unaddressed. This proposition resonates with Dudu (2014a), who posits that 1:30 is a desirable standard teacher-learner ratio in South African high schools. However, he laments that this is not the current state of affairs in South African schools, by stating that,

> *the high teacher to learner ratio makes it difficult for teachers to implement different strategies when teaching Science subjects … and teachers also find it difficult to offer guidance to fulfil their duties as required by CAPS, one of which is the use of IBL in teaching science (Dudu, 2014b).*

2.4.2.3 Teacher perceptions and beliefs

Research indicates that, even though IBL is now gaining traction in science pedagogy, very little research has been done in the South African context regarding the implementation of IBL (Ramnarian & Hlatshwayo, 2018:2). South African scholars who advocate an inquiry-based pedagogy suggest that teacher beliefs and perceptions influence the practice of IBL (Dudu, 2014a; Ramnarian & Hlatshwayo, 2018). However, Dudu (2014b) argues that many science teachers in South African high schools hold mixed conceptions and perceptions about the nature of scientific inquiry. To some teachers, scientific inquiry is characterised by a universal, step-by-step scientific method (Dudu, 2014a). Kazeni, Baloyi and Ghaigher (2018) argue that IBL is a science pedagogy for developing learners' construction skills through creative thinking during scientific investigations.

In a study conducted by Ramnarian and Hlatshwayo (2018), teacher beliefs were found to be a major factor that influences whether teachers use inquiry-based pedagogy in teaching science subjects. Teachers' pedagogical orientations are largely dependent on their beliefs, and if they are inquiry-driven, they are more likely to practice IBL; if they hold beliefs that are not inquiry-driven, they are unlikely to be encouraged to practice inquiry-based teaching and learning (Ramnarian & Hlatshwayo, 2018).

2.4.2.4 Rigid curriculum

Dudu (2014b) reports on a study conducted at a few high schools in the North West province of South Africa. Participating teachers mentioned that there was no flexibility in the science curriculum under the CAPS, which does not allow the maximum implementation of IBL (Dudu, 2014b). Life sciences teachers are, therefore, expected to implement IBL in their practice within a rigid curriculum, which has to be completed in a set time frame. Such a practice contradicts the principles of IBL, because learners are expected to come up with findings that are in line with the curriculum.

2.4.2.5 Lack of laboratories and laboratory equipment

South African scholars who advocate an inquiry-based pedagogy for teaching sciences assert that most South African science teachers have to implement IBL in the absence of science laboratories and relevant equipment to conduct authentic inquiry activities (Tsakeni, 2018; Motlhatlhedi, 2015). Tsakeni (2018:196) postulates that “the lack of laboratory facilities, equipment and materials is one of the factors that literature confirms as crippling for the implementation of inquiry-based practical work”. Furthermore, learners in under-resourced schools often lack laboratory facilities and the relevant apparatus to perform hands-on scientific investigations (Tsakeni, 2018). Therefore, science educators in general, and life sciences educators in particular are faced by challenges that limit the efficacy of their implementation of IBL, because most scientific investigations have to be carried out in laboratories, using relevant apparatus.

According to Motlhatlhedi (2015), the lack of equipment and science laboratories is an impediment to the implementation of IBL as an intervention achieve to effective science teaching and learning. In a study conducted at South African schools, she found that the schools lacked proper equipment and did not have science laboratories to implement IBL (Motlhatlhedi, 2015). It is, therefore, from the evidence presented, clear that most South African high schools offering life sciences are yet to witness the efficacy of IBL, since it requires sufficient equipment and the availability of science laboratories.

2.5. SOCIAL CONSTRUCTIVISM AS A THEORETICAL FRAMEWORK

The theoretical framework guiding this study is social constructivism. Supporters of social constructivism argue that knowledge is socially constructed through interaction with other people and the environment one lives in. They emphasise the importance of culture and context in understanding what occurs in society, and claim that knowledge is constructed based on this understanding (Kim, 2006; Au, 1998). It is on the basis of this description of social constructivism that I used it as a theoretical framework, as the present study is about IBL, which is mainly characterised by the construction of knowledge by learners who interact with one another. The concepts, therefore, corroborate one another and make social constructivism relevant to the study.

A second level of reality is “achieved when experiential invariants are formed out of sensory material from different sources: something seen and touched is more real than something learnt through visual signals alone” (Gredler, 1997:93). Other academics agree on the significance of reality and experience for how learners have to be taught. Applefied (2000:41) advocates for the notion that “constructivism is an epistemological view of knowledge acquisition emphasising knowledge construction rather than knowledge transmission and the recording of knowledge conveyed by others”.

Au (1998) states that, “at the heart of social constructivism is a concern for lived experience or the world as it is felt and understood by social actors”. The present study took shape through the work of Vygotsky, who is regarded as the father of social constructivism, because his theory recognises the significance of social interaction between individuals, such as occurs in the classroom. Vygotsky believed that the “internalisation of higher mental functions involved the transfer from the inter-psychological to the intra-psychological; that is, from socially supported to individually controlled performance” (Au, 1998). In simpler terms, Vygotsky argued that an individual learns or constructs knowledge within a social context to which he/she brings some socially constructed knowledge based on which new knowledge will be constructed (Au, 1998:300).

Pallincaster (1998:351) agrees, and states that, "as learners participate in a broad range of joint activities and internalise the effects of working together, they acquire new strategies and knowledge of the world and culture". Furthermore, he makes reference to the zone of proximal development, which is one of the important tenets Vygotsky used to give a sound explanation of how learning and construction of knowledge take place through social constructivism. It implies that a child shows two levels of development, that is, actual development and potential development. The actual encompasses those accomplishments a child can demonstrate alone or independently, while the potential refers to what a child can achieve through assistance by a more knowledgeable other during meaningful interaction (Pallincaster, 1998).

2.5.1 Principles of social constructivism

Pallincaster (1998) explains that social constructivism is governed by nine important principles:

- *Group learning*: Effective learning is promoted by constructing knowledge in groups.
- *Sharing ideas*: Knowledge is constructed through social interaction and by sharing ideas, rather than individual experiences.
- *Pre-existing knowledge*: Learners' ability to learn relies to a large extent on what they already know and understand, and the acquisition of knowledge should be an individually tailored process of construction.
- *Real-world practical learning*: Supports the learner by providing guidance for real-life experiences. Learners work together to understand reality in learning situations.
- *Guide on the side*: The teacher is a guide, facilitator and co-explorer who encourages learners to question, challenge and formulate their own ideas, opinions and conclusions.
- *Situated learning*: Knowledge is constructed socially and everyone has different social experiences, resulting in multiple realities.

- *Interactive learning*: Individuals create or construct their own new understandings or knowledge through the interaction of what they already know and believe, and the ideas, events and activities with which they come into contact.
- *Student-centred*: Social constructivism emphasises each student's interests, abilities, and learning style. The learners take an active part in deciding what they learn, how they learn and how they can evaluate what they have learnt.
- *Authentic*: Meaningful learning occurs in real-world, related authentic tasks and by means of interaction and collaboration between experts and peers.

2.5.2 Social constructivism in the science class

According to Duit (1996), social constructivism explains that knowledge is constructed through social interaction. Science instruction in the social constructivist class is aimed at providing learners with scientific knowledge, in such a way that they not only understand the scientific concepts and principles, but they also learn how the knowledge they construct is significant to their lives and the lives of other human beings (Duit, 1996). Social constructivist pedagogical approaches are entirely learner-centred. They take learners' beliefs and conceptions seriously, which means the learners take an active role in the learning process, unlike the inactive role they would take in the traditional approach that only recognises the teacher as an active party in the learning process (Duit, 1996).

Kim (2006) agrees that interaction between learners in the science class is significant for the construction of meaningful knowledge. Amineh and Asl (2015:12) also agree, and emphasise that "learners construct new understandings using their current knowledge. Learning is not passive, but involves learners who ask questions actively; they have to find answers themselves and this culminates in the development of meaningful knowledge". Furthermore, "social constructivist teaching approaches emphasise reciprocal teaching, peer collaboration, cognitive apprenticeship, problem-based instruction, web quests, anchored instruction, and other methods that involve learning with others" (Amineh & Asl, 2015). Classroom practice in social constructivist lessons is characterised by teachers being facilitators, who support from the back rather than lecturing from the front in the traditional role played by the teacher (Amineh & Asl, 2015).

2.5.3 Scaffolded inquiry as a conceptual framework

The present study followed guided (scaffolded) inquiry as a conceptual framework according to the scholars cited in this section. However, the concept scaffolded inquiry was used to pre-empt confusion with the meaning of guided inquiry and to acknowledge that there are other strands of IBL characterised by teacher guidance. Kuhlthau *et al.* (2007:2) posit that "guided inquiry helps learners gain competence by being guided by teachers, to find and use a variety of sources of information and ideas to increase their understanding of a problem, topic or issue". It is against the constructivist nature of knowledge creation that guided inquiry was chosen as a conceptual framework, alongside social constructivism, which is the theoretical framework of the study. Hansen (2002) defines guided inquiry as the type of instruction in which "the teacher helps the learners develop inquiry investigations in the classroom". Furthermore, the learners help the teacher to decide how to proceed with the investigation (Hansen, 2002).

The conceptual framework guiding this study is based on the approach outlined by Friedler *et al.* (1990). Findings by Kuhlthau *et al.* (2007) emphasise the pertinent role played by the teacher's guidance during the inquiry process. Inquiry is an imperative means of science learning, but it is a daunting activity when learners work entirely on their own (Kuhlthau *et al.*, 2007). Learners need intensive guidance and intervention throughout the process of inquiry to elicit deep learning and personal understanding (Hansen, 2002). Furthermore, the work of Kuhlthau *et al.* (2007) and Hansen (2002) reveals the significance of creating a third space for the learner, which refers to the space where what the learner knows about the world and the curriculum content overlap to create a meaningful learning.

Guided inquiry involves the following steps in the classroom, which clearly indicate the roles played by both the teacher and the learners in constructing knowledge through inquiry:

The learners, under the guidance of the teacher, **identify and define** a scientific problem. The presence and contribution of the teacher does not mean the learning process is dominated by the teacher. Learners still have to identify the problem and the teacher only gives guidance to the learners, who are working in groups to corroborate social constructivism.

The second step in guided inquiry is **orienting and asking questions,** during which learners make observations of scientific phenomena they are interested in. The teacher facilitates the process of formulating the questions, which can be investigated by scientific means.

After formulating sound scientific questions, learners engage in the third step of guided inquiry, **stating a hypothesis**, which is the formulation of the relations between variables and predicting the answer to the questions. The learners propose tentative scientific answers to the questions they formulated during the second step of their inquiry activity.

The learners, guided by the teacher, **design and plan an experiment** to test the formulated hypothesis. The learners still take ownership of their learning as they decide how the experiment will be conducted. This is the stage where the learners plan how the experiment will be conducted and what apparatus will be used during the investigation. In instances where learners are going to conduct investigations that do not involve experiments, they engage in designing an accessible and relevant action. Learners decide on the sources from which they will collect data, using sources such as the internet and libraries.

Observation and collection of data are the next steps, where the learners conduct scientific investigations and make observations to draw the necessary conclusions. The teacher does not provide learners with information, but facilitates their activity, which ensures that the learning process does not deviate from the basic tenets of scientific inquiry learning.

In the next step, learners **analyse and interpret data** based on their observations, which involves confirming the hypothesis.

Conclusions are drawn by the learners following the observations they made during their observations during the investigations.

Communication is the final step, whereby the learners communicate their findings with others in open discussions. The teacher decides how the learners communicate their findings, which could be in the form of presentations, with each group appointing a member to present the findings, or learners can engage in an open classroom discussion, guided by the teacher. Communication also characterises the entire process of guided inquiry, since, during all the stages, learners communicate with one another.

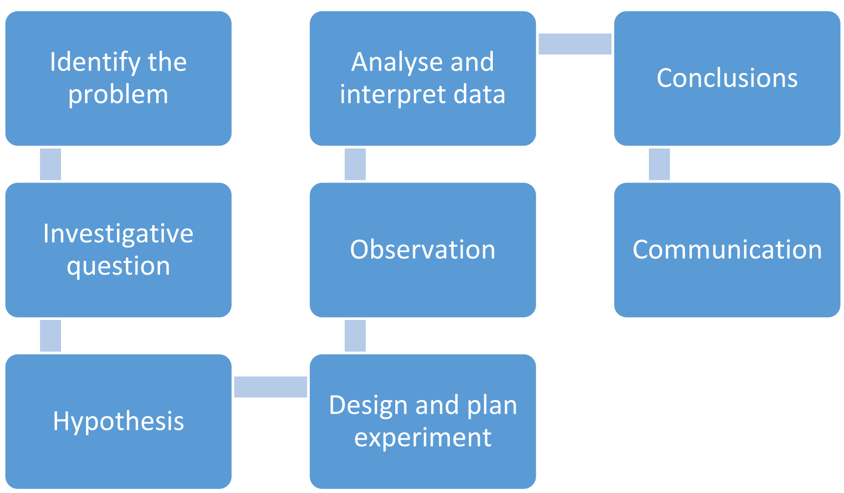

Figure 2.1: Guided (scaffolded) inquiry conceptual framework

2.5.4 Relationship between social constructivism and inquiry-based learning

The present study used social constructivism as a theoretical framework and guided inquiry as a conceptual framework because the basic tenets show that the one supplements the other, and they are both central to recent education transformation all over the world. Walker and Shore (2015) posit that IBL is rooted in the principles of social constructivism. In describing what IBL is, they indicate that "inquiry-based learning is learner-centred, based on student interests and curiosity" (Walker & Shore, 2015). It is noteworthy that the advocates of social constructivism describe social constructivism as a learner-centred approach, which recognises the importance of learners' beliefs, interests and curiosity (Pallincaster, 1998; Duit, 1996; Au, 1998).

Similarly, Botha (2016:76) posits that,

> *IBL requires more than simply answering questions or a right answer. It espouses investigation, exploration, search, quest, research pursuit and study. It is enhanced by involvement with a community of learners; each one learning from the other in social interaction.*

In light of this proposition, I believe social constructivism corroborates the principles of learning through guided inquiry. Central to both social constructivism and guided inquiry are the significance of and a belief that social interaction is a pivotal aspect of learning.

Kuhlthau *et al.* (2007:13) explain that "every educator has a theory of learning that forms the basis of the instruction and the learning environment he or she provides for learners". Furthermore, they argue that "guided inquiry has a solid theoretical foundation, grounded in the constructivist approach to learning" (Kuhlthau *et al.,* 2007:13). Guided inquiry has its roots in constructivism and the advocates of both believe in the notion that learning is not about transmitting knowledge to learners, but that teachers should create meaningful learning environments in which learners interact with one another to construct knowledge.

2.6. GAPS IN THE LITERATURE

My review of the literature, specifically on the practices of IBL in life sciences classes, revealed three main strands that are in line with my secondary research questions. Firstly, local and international literature reveals that teachers, both abroad and locally, welcomed IBL, though from different perspectives. Some teachers acknowledge the efficacy of IBL for teaching science subjects, and scholars argue that it leads to improvement of learner performance in science subjects. However, there is no precise explanation for what teachers perceive IBL to be in relation to their daily practices. Perceptions in this regard are mainly categorised as whether teachers feel they should or should not apply IBL in their teaching. This study, therefore, sought to generate data describing what life sciences teachers regard IBL to be in their own practices.

Secondly, the literature refers to IBL teacher practices in the classroom. International and local literature fails to reveal precisely whether teachers who advocate for IBL are using one form of inquiry specifically, or whether they are in the process of moving along the continuum, from the lower to higher levels of inquiry. The present study, therefore, sought to expound explicitly on the strands of IBL life sciences teachers practice in the classroom. Furthermore, professional development was the main contextual factor that literature bemoaned as derailing the implementation of IBL in science classrooms. Internationally and locally, professional development in IBL pedagogy is still largely uncertain. However, the literature does not reveal the teachers' levels of competency, and it is silent about the forms of professional development teachers are exposed to.

What is even more troubling about the review is that few studies addressed IBL practices in life sciences teaching specifically. Most scholars report on trends in IBL pedagogy in the teaching of science subjects, like physical sciences. The fact that very little research into life sciences IBL pedagogy is reported on, indicates an oversight by researchers, especially local researchers.

2.7. SUMMARY OF THE CHAPTER

The literature review started by exploring life sciences education internationally and in the South African context. The chapter also explored literature relating to the use of IBL in life sciences teaching in the international and local landscapes. The last section of the chapter focused and expounded on social constructivism as a theoretical framework, and guided inquiry as a conceptual framework, as well on how the two corroborate with each other.

The next chapter will provide details of the qualitative methodology and research design that was used to explore life sciences teachers’ practices of inquiry-based instruction.

CHAPTER 3: RESEARCH METHODOLOGY

3.1. INTRODUCTION

All contemplated research becomes successful when it follows a detailed plan, which, in this case, outlines the methodology by which the current study was guided. Kothari (2004:61) defines research methodology as "a way to systematically solve the research problem and in it we study the generally adopted methods by a researcher in studying his research problem along with the logic behind them". This chapter will describe the methodology of the present study and present details about the participants, including when, where and how data were collected. It will also describe and explain how the generated data were analysed.

The chapter will begin by stating the focus of the present study, followed by the paradigm, which is interpretivism. After a detailed discussion of the paradigm, I will present and discuss the research approach and design that were used. A qualitative research approach and a case study research design were employed by the study. Data collection involved semi-structured interviews and, for triangulation, non- participant observation, which were relevant for generating appropriate qualitative data to respond to the research questions of the study. The collected data were analysed using thematic data analysis, which is relevant to the analysis of qualitative data.

The current study explored the practice of IBL in South African life sciences classrooms. It specifically explored what life sciences teachers do when they practice and implement IBL, what perceptions they have about IBL, what strands of IBL they use in their practice, and what the contextual factors are against which the teachers have to implement IBL in the South African context. To achieve this, the study sought to answer the following main research question:

How is IBL practiced in life sciences classrooms?

To answer the main research question in the present study, the following sub-questions were addressed:

- How do life sciences teachers perceive the use of IBL in life sciences classrooms?
- What strands of inquiry are currently practiced in the teaching of life sciences?
- How do contextual factors influence the practice of IBL in the teaching of life sciences?

The aim of the present study was to find out how inquiry-based life sciences teaching is practiced at the three selected high schools in Standerton.

To achieve the aim mentioned above, the study pursued the following objectives:

- To find out what life sciences teachers' perceptions about IBL are;
- To explore the strands of inquiry practiced by life sciences teachers in the three selected schools; and
- To explore the contextual factors that influence the implementation of IBL in life sciences classrooms.

3.2. PHILOSOPHICAL UNDERPINNING

The present study followed interpretivism as a research paradigm. Mackenzie and Knipe (2006:3) posit that interpretivist approaches to research aim to understand the world of human experience. Furthermore, reality is constructed through social interaction, and the researcher relies on the views of the participants regarding the phenomenon under study (Mackenzie & Knipe, 2006). According to Guba and Lincoln (1994:111), "the variable and personal nature of social constructions suggests that individual constructions can be elicited and refined only through interaction between and among the investigator and respondents".

Interpretivism was chosen as relevant for this study based of the nature of the research questions. Life sciences teachers who practice IBL were sampled as participants. They experienced the teaching of life sciences in general and its teaching through IBL in particular. The teachers shared their experiences through their voices during semi-structured interviews. There was interaction with the teachers during the interviews, which gave me access to data from the participants who have experienced the use of IBL to teach life sciences. This means the classroom experiences were observed through the eyes of the participants (Mackenzie & Knipe, 2006).

Denzin and Lincoln (1998:221) postulate that,

> *the world of lived reality and situation-specific meanings that constitute the general object of investigation is thought to be constructed by social actors, and particular actors, in particular places, at particular times, fashion meaning out of events and phenomena through prolonged, complex processes of social interaction involving language, history and action.*

The participants were teachers who lived the reality of teaching life sciences, and the study sought to make meaning of the teachers' experiences through structured interviews and non-participant observation. I also contributed to the process of meaning making through involvement with the participants by interviewing them, observing their classroom practices, compiling field notes from the observations, and the process of reporting the data.

3.3. RESEARCH APPROACH

Kohn and Christiaens (2012) explain that qualitative research involves the collection of non-numeric data, such as words and narratives. Qualitative research methods allow participants to speak in their own voices, rather than conforming to the categories and terms imposed on them by others. People or phenomena are studied in their natural settings. Researchers believe that "action can be understood when it is observed in the setting in which it occurs naturally" (Kohn & Christiaens, 2012:82). Hoepfl (2017:47) agrees, by stating that qualitative research uses a naturalistic approach that seeks to understand phenomena within their natural contexts, and argues, furthermore, that this research approach produces findings that cannot be produced by any statistical research, such as quantitative research.

Qualitative research was employed because it is appropriate for the nature of the present study, which does not rely on numerical data. Furthermore, this approach to research is relevant to the present study because the meaning of the activities of the teachers in their practice of IBL was investigated. The participants and the phenomenon – the practice of IBL to teach life sciences – were studied in their natural contexts – the classroom – and I was primarily engaged with the participants to make sense and gain an understanding of participants' actions in their contexts, which confirms that the case study research design was appropriate for this study (Gaya & Smith, 2016).

Scholars emphasise the importance of qualitative research by explaining the shortcomings of quantitative research. These arguments confirm that qualitative research was the right approach for this study. Furthermore, the research questions guide the decision to use a particular research methodology. According to Flick (2010:14), "despite all the methodological controls, influences from interests, social and cultural backgrounds are difficult to avoid in quantitative research". Given the nature of the study as reflected by the research questions, quantitative research would not have been the best research method for this study. Qualitative research is relevant to the present study, since no numerical data was used to answer the research questions.

Kohn and Christiaens (2012) emphasise that qualitative research allows the researcher to see the phenomenon under investigation through the eyes of the participant. They explain that qualitative research involves the collection of nonnumeric data, such as words and narratives. Qualitative research methods allow participants to speak in their own voices, rather than conforming to the categories and terms imposed on them by others; and people or phenomena are studied in their natural settings (Kohn & Christiaens, 2012). I collected data from the participants in their natural settings – the classrooms and where they practice IBL in teaching life sciences.

The present study was guided by the eight characteristics of qualitative research outlined in Hoepfl (2016:47), though these characteristics are not, however, regarded as the absolute characteristics of qualitative research. Various authors list these characteristics as follows:

- Qualitative research uses the natural setting as the source of data collection, with the researcher observing, describing and interpreting these settings as they are.
- In all phases of data collection, the researcher acts as the human instrument of data collection.
- Qualitative researchers use inductive data analysis.
- Qualitative research reports are descriptive, and incorporate expressive language and voice in the text.
- Qualitative research has an interpretive character that is aimed at discovering the meaning events have for the individuals who experience them and the interpretation of those meanings by the researcher.
- Qualitative researchers pay attention to the idiosyncratic as well as the pervasive, and seek the uniqueness of each case.
- Qualitative research has an emergent design, and researchers focus on this emerging process and the outcomes or product of the research.
- Qualitative research is judged using criteria for trustworthiness.

3.4. RESEARCH DESIGN

3.4.1 Case study

A research design has to be consistent with the nature of the study, and the choice is based largely on the nature of the research questions. A design that is appropriate to the nature of the present study is the case study design. The case study design corroborates research conducted through an interpretivist lens, and even though positivists use it in their research, most interpretivists use it too (Petty, Thomson & Stew, 2015). The present study questioned "how" by exploring the implementation part of IBL, specifically in the context of life sciences teaching.

Case study is, therefore, congruent with the postulations of Baxter and Jack (2008:), who posit that case studies are relevant when studies seek to answer questions such as how and why; when the researcher cannot manipulate the behaviour of those involved in the study; when the researcher wants to cover the contextual conditions because they are relevant to the phenomenon under study, and when the boundaries between the phenomenon and the context are not clear. Observations were conducted in classrooms, and teachers were interviewed, which elicited data that are primarily based on the natural context of the phenomenon under study, in this case, IBL. These data collection methods enabled the study of IBL in its natural context, the classroom.

Creswell (2007:73) posits that "case study research involves the study of an issue explored through one or more cases within a bounded system". The current study corroborated this definition, in the sense that Standerton was the case selected, from where four life sciences teachers at three high schools were selected, interviewed and observed while presenting lessons. The issue studied in this case was the practice of IBL in life sciences teaching. I subscribed to the descriptive case study, which is used to describe an intervention or phenomenon and the real-life situation within which it occurs (Baxter & Jack, 2008), because a report was compiled of the events observed during data collection by observing the lessons presented by the life sciences teachers (Noor, 2007).

Gaya and Smith (2016) agree on the description of case study research as involving the investigation and analysis of a single case or collective cases. The authors add that, in case study research, "investigators adopt the research design to understand a real-life phenomenon under important natural conditions that are relevant to the occurrence under investigation" (Gaya & Smith, 2016). The phenomenon explored in the present study was IBL and how life sciences teachers implement it in their teaching, which took place in the schools and classrooms that are natural contexts of the phenomenon. This corroborates the views of Yazen (2015), who posits that case study is an empirical inquiry focusing on contemporary phenomena in their real-life contexts, and the boundaries between phenomena and their contexts are not clearly evident.

Furthermore, case studies are conducted according to the steps identified by Creswell (2007:73), who outlines several procedures available for conducting case-study research.

- The researcher must determine if case study research is appropriate for the proposed study by ensuring that there are identifiable cases with boundaries, and must seek to create an understanding of the cases.
- The researcher needs to identify the cases. To do this, four teachers from three high schools in Standerton were selected, which made the study a multiple case study research project.
- Data collection in case study research is extensive and involves observations, interviews, documents and visual materials. In the present study, semi-structured interviews and non-participant observation were used to generate data that would answer the research questions.
- The analysis of the data can involve holistic analysis of the entire case. In this case, I used thematic data analysis to analyse the data.
- In the final interpretive phase, the researcher reports the meaning of the case, whether that meaning comes from learning about the issue of the case, or learning about an unusual situation.

3.5. SAMPLING METHOD

From the definitions of sampling, that of Gentles, Charles, Ploeg and McKibbon (2015) was selected. The authors define sampling in its broadest sense as "the selection of specific data sources from which data are collected to address the research objectives" (Gentles, *et al., 2015:1775)*. This definition implies that, for any proposed study, data will have to be collected from a certain number of sources, which represent the entire population. The present study sought to make sense of how life sciences teachers practice IBL in their classrooms. It was, therefore, necessary to subscribe to certain sampling techniques to select teachers from high schools in Standerton to generate data that would be used to answer the research questions.

3.5.1 Purposive sampling

Participants were selected purposively. The adaptation of purposive sampling to the present study was fashioned after several scholars who describe sampling in qualitative research (e.g. Palys, 2008; Maree, 2014; Gentles *et al.*, 2015). The relevance of purposive sampling to the present study was mostly justified by the description of the most salient tenets of purposive sampling by Gentles *et al.* (2015), who emphasise that it is one of the sampling methods that are generally relevant to the practice of qualitative research and the case study research design. Scholars who advocate qualitative research and case study research designs explain that purposive sampling enables researchers to select information-rich cases. This means that the participants are selected because they possess valuable information regarding the phenomenon being studied (Gentles *et al.*, 2015).

Ilker (2016:36) describes purposive sampling as "the deliberate choice of a participant due to the qualities the participant possesses. It is a non-random technique that does not need underlying theories or a set number of participants, which means the researcher decides what needs to be known and sets out to find people who can and are willing to provide the information by virtue of their knowledge or experience". Palinkas, Horwitz, Green, Wisdom, Duan and Hoagwood (2015:542) state that purposeful sampling "involves identifying and selecting individuals who are especially knowledgeable about or experienced with the phenomenon of interest". The phenomenon studied in this study was using IBL in life sciences teaching. I purposively selected teachers who were knowledgeable in the area of life sciences teaching in general and teaching it through IBL in particular.

Participants were selected purposively because the present study focused on the practice of IBL in the teaching of life sciences, and only teachers who practiced it and had knowledge of IBL, particularly in the context of life sciences teaching, were selected. Four teachers who taught life sciences in the FET phase were intentionally selected from three high schools in Standerton. At one of the three high schools, a participant indicated that she had a colleague who also practices IBL in life sciences teaching, who was then also selected through snowball sampling (discussed in section 3.5.2). The three high schools were purposefully selected based on the fact that they offered life sciences and represented various contexts and backgrounds.

South African schools are categorised in relation to the country's political history. Radebe (2015) posits that the apartheid regulations in South Africa are reflected in the country's education system. Laws, such as the Bantu Education Act of 1953, enforced racial segregation of education facilities, which saw white learners having access to well-resourced schools called Model C schools in the 1980s (Radebe, 2015). Other racial groups, including blacks, had access to poorly resourced schools in the townships and rural areas (Radebe, 2015). The aftermath of the apartheid policies is reflected in the current education system, because schools are still characterised by tremendous differences. In the present study, one high school is a former Model C school in Standerton; one is a township African school in a suburb of Standerton, and the other one is an African rural school, also in Standerton. The schools in three different categories were selected because they each had teachers who practised IBL in life sciences teaching, which I learnt through a word of mouth from the life sciences subject advisor. The four teachers I chose as participants were teaching life sciences across the FET phase; during informal conversations they stated that they practised IBL. Selecting these specific teachers enabled me to gain access to information-rich cases, because they had experience of teaching life sciences in general, and the practice of IBL in particular. The fact that they were from three schools with different contextual factors enabled triangulation of the data and generating meaning relating to the way contextual factors influence the practice of IBL (Gentles *et al*., 2015).

Palys (2008) states that purposive sampling means the researcher's way of sampling must be tied to study objectives. This was relevant to the present study, because the goals were to elicit, from the research sites, qualitative data, collected through the interpretivist lens, that would create meaning regarding how IBL is practiced. Maree (2014) agrees with other scholars that purposive sampling, which is best used in qualitative research, includes settings, incidents, events and activities, in addition to the selection of the participants. This sampling technique is explained by Maree (2014) as selecting participants according to predetermined criteria that are relevant to a particular research question. To align the present study with this requirement, participants were selected because they taught life sciences, practiced IBL, and worked at schools that offer life sciences and that have laboratories where inquiry-based life sciences practical work can be done.

Ilker *et al.* (2016) describe purposive sampling as,

> *a deliberate choice of a participant due to the qualities the participant possesses. It is a non-random technique that does not require underlying theories or a set number of participants, which means the researcher decides what needs to be known and sets out to find people who can and are willing to provide the information by virtue of the knowledge or experience.*

This explanation illustrates the flexibility of purposive sampling. Participants were selected at the researcher's own discretion, because they possessed the information needed by virtue of knowledge and experience of the teaching of life sciences through the application of IBL (Ilker *et al.*, 2016). Creswell and Clark (2011, in Palinkas *et al.,* 2013) argue that "purposeful sampling involves identifying and selecting individuals who are especially knowledgeable about or experienced with the phenomenon of interest".

The sampling method explained above is relevant to this study because of the criteria outlined briefly above. In this study, data were collected from three preselected high schools in Standerton, a small town in Mpumalanga province. The participants were life sciences educators at these high schools, who taught life sciences across the FET phase.

The sample included a teacher from a former Model C high school, who had been teaching life sciences for three years, one teacher from an African township school, who had been a teacher for seven yes but had been teaching life sciences for five years, and one teacher from an African rural school, who had been teaching life sciences for four years. The fourth teacher was from the former Model C school too, and had been teaching life sciences for seven months. This explanation corroborates the main distinguishing characteristic of purposeful sampling, which is the application of preselected criteria to choose a sample from the population so as to elicit the contemplated results.

3.5.2 Snowball sampling

An additional participant teacher was added to the study through snowball sampling. During an interview with Linda, a teacher from a former Model C high school, she indicated that her colleague also practised IBL to teach life sciences. Naderifar *et al.* (2017:3) posit that, "after gaining access to preliminary samples, the samples begin to introduce other people to take part in the research". Parker (2020:3) argues that "researchers usually start with a small number of initial contacts, who fit the research criteria and are invited to become participants within the research". The method is relevant to the present study, because at least one participant was identified and chosen to be a participant because of a referral by a participant who was part of the initial sample.

3.6. DATA COLLECTION

Data collection is an integral part of any research project that is conducted either qualitatively or quantitatively, because it generates data that are required to answer the research questions. In the present study, data collection occurred through semi-structured interviews, and triangulation was achieved by non-participant observation. The relevance of the data collection methods used in the present study will be explained briefly and described.

3.6.1 Semi-structured interviews

Semi-structured interviews were used as the main data collection methods. I used an interview protocol (Appendix A) as a data collection instrument. The interviews were audio-recorded and transcribed during data analysis. Mathers *et al.* (2002) posit that an interview is an important technique that involves verbal communication between the researcher and the participant. There are different forms of interviews, and I chose to employ semi-structured interviews, which involve open-ended questions that allow both the interviewer and interviewee to discuss some topics in detail, and enable the interviewer to probe for more clarity where the answers are not clear (Mathers *et al.*, 2002).

It was imperative to use semi-structured interviews in this study as it allowed flexibility for follow-up questions. This was instrumental in instances where the participants did not provide satisfactory responses to the questions. Such a flexibility is relevant to qualitative studies (Pathak & Intratat, 2015). Semi-structured interviews were relevant for the present study as they are flexible and consistent with small-scale research, and since only four life sciences teachers were interviewed (Pathak & Intratat, 2015). Semi-structured interviews are ideal in a situation where research involves a small number of participants, which was the case with this study as only four participants were selected.

Stewart, Treasure and Chadwick (2008:296) explain that "semi-structured interviews consist of several key questions that explain the areas to be explored in a study, but also allow both the interviewer and interviewee to diverge in order to pursue an idea in more detail". In the present study, the teachers interviewed were knowledgeable about the teaching of life sciences and the practice of IBL. The semi-structured interviews used predetermined questions that guided the teachers to divulge relevant information; where necessary, follow-up questions were asked to elicit more data that could not be revealed without probing. Doing so provided more data that were relevant to the research questions (Stewart *et al*., 2008).

Advocates of qualitative research claim semi-structured interviews are relevant for data collection (Abawi, 2013; Maree, 2014). The schools were visited to observe and interview participating teachers. One of the advantages of semi-structured interviews is that the researcher is present to probe and ask more questions as a way of seeking clarification if a respondent gives a vague answer (Abawi, 2013). I administered semi-structured interviews for each of the four participants in the study. I conducted one interview with each of the four participants over a period of two months in the third term, which allowed sufficient time to accommodate the lesson observations that followed for each participant. The interviews were conducted at the schools where the participant teachers were working. The participants had each arranged spaces in their respective classrooms at convenient times when they had no learners or lessons to run to allow for confidentiality. I requested for permission from each of the participants to audio record the interviews.

3.6.2 Observation

In addition to semi-structured interviews, observation was used to collect data for the purposes of triangulation. I used an observation protocol (Appendix B) and field notes to collect data during lesson observations. In the present study, all four participants were observed presenting their IBL lessons – one lesson observation for each participant. Since not all life sciences lessons are presented using IBL, each participant informed me about the period in which they would be conducting IBL lessons. Each participant was observed presenting a lesson after an interview that was used for triangulation, which took place over a two-month period. Unlike interviews, observation provides a deeper understanding of the phenomenon, since it provides information on the context in which events occur, and may enable the researcher to see what the participants themselves do not see or are unwilling to discuss (Hoepfl, 1997). Maree (2014) postulates that observation is a way of gathering data by watching behaviour and events, or noting physical characteristics in their natural settings. In its simplest meaning, observation is described as a data collection method that involves the researcher observing the phenomenon under study (Maree, 2014).

A non-participant observer role was assumed; the lesson presentations were observed without the researcher playing any active role or interacting with the teachers. Instead, their behaviour was recorded (Urquhart, 2015:28; Maree, 2014). Observing phenomena in their natural settings fit into the case-study research design and qualitative research methodology. It is because of this tenet that observation was selected as one of the data collection methods. Teachers who practice IBL were observed while presenting lessons; this took place in their classrooms, which were the natural contexts of the study, since the pedagogical approach is applied in the classroom.

Maree (2014) postulates that observation can be overt, which means that the participants are aware that there is someone observing their behaviour, or covert, which means participants are observed by a researcher without them knowing they are being observed. Considering the ethical issues relating to observation, it was decided to observe the teachers' presentations of lessons overtly.

One of the advantages of observation is that it is a qualitative data collection method that collects first-hand or primary data from the natural context of the phenomenon being investigated (Maree, 2014). The following are some of the advantages of observation in qualitative research, as identified by Maree (2014).

- Data are collected where and when an event or activity is occurring.
- It does not rely on people's willingness to provide information.
- It allows the researcher to see what people do, rather than what people say they do.
- The researcher is directly involved in the collection of data making meaning of the event, activity or phenomenon observed.

Fox (1998) argues that using observation as a data collection method requires a researcher to be selective when collecting data. The research questions and focus were used to ensure that only relevant phenomena at the research sites were included as part of the observed data. Field notes and audio recordings were taken of only the activities related to what the teachers did while practicing IBL (Fox, 1998). The basic principles of non-participant observation were followed, in particular, ensuring that I remained unobtrusive, and did not engage with the lesson presentation in any way that would influence the activities, to ensure that biases were limited (Fox, 1998; Maree, 2014).

3.7. DATA ANALYSIS

One of many definitions of data analysis is that of Kawulich (2004:2), who postulates that it is “a process a researcher uses to add data to a story and its interpretation and during the process data are organised, data are reduced through summarisation and categorisation, and themes in the data are identified and linked”. The technique a researcher chooses to analyse data has to be consistent with the research questions, the research design and the research methodology. Narrative analysis and thematic data analysis were used for this study.

3.7.1 Thematic data analysis

Data collected for this study through semi-structured interviews and lesson observations were analysed using thematic data analysis. Thematic data analysis is described by several qualitative researchers (Braun & Clarke, 2006; Nowell, Norris, White & Moules, 2017) as a method for identifying, analysing and reporting patterns (themes) within data; it minimally organises and describes the data set in detail (Braun & Clark, 2006). The themes were predetermined and informed by the theoretical conceptual frameworks and literature engaged in Chapter 2. Braun and Clarke (2006) define thematic analysis as “identifying, analysing and reporting patterns (themes) within data”; they also state that “it minimally organizes and describes your data set in (rich) detail”. Subscribing to thematic analysis, the data collected for this study were organised according to relevant themes that were responsive to the research questions identified.

The present study followed a qualitative research methodology, which is one of the reasons for subscribing to thematic analysis, since scholars agree that it is consistent with qualitative research (Nowell *et al*., 2017). Thematic analysis was chosen as an underlying data analysis method, because an effectively conducted thematic analysis ensures trustworthiness of the findings of a study (Braun & Clarke, 2006; Nowell *et al*., 2017). Therefore, to ensure trustworthiness, the central criteria of a sound qualitative study were applied to ensure that the study yielded the intended outcomes.

Nowell *et al*. (2017) posit that an effectively conducted thematic analysis is done logically through six important steps. They also note that, in the literature, there is no evidently identified conventional way to apply the method to analyse qualitative data. The flexibility of thematic analysis is another reason for subscribing to it for analysing data. The following is a summary of the steps that need to be followed by researchers who apply thematic data analysis, as outlined in Nowell *et al*. (2017) and Braun and Clarke (2006). I used predetermined themes that related to my secondary research questions. Data were classified into three themes that were framed as follows, since I had three secondary research questions.

3.7.1.1 Phase 1: Familiarise yourself with your data

The process in this phase involves researchers immersing themselves in the data that have been collected, which can be through reading or listening to audio recordings made during interviews (Nowell *et al*., 2017). It was planned to collect data for this study through semi-structured interviews, observations and document analysis. The teachers were observed practicing IBL in their classrooms once each, and they were interviewed once each to ensure a prolonged engagement with data.

3.7.1.2 Phase 2: Generate initial codes

During this phase, I engaged with the data that had been collected to make meaning. The assistance of student colleagues was engaged to ensure no partiality with regard to how the data was interpreted, to prevent any forms of bias that could arise. This was a form of peer debriefing. Thereafter the initial codes were generated. Braun and Clarke (2006:16) postulate that the second phase begins by engaging with the data, thoroughly reading it and familiarising oneself with the data. An initial list of ideas can then be generated about what is interesting in and about the data. During this phase, codes that were descriptive of how participant teachers perceived IBL in teaching life sciences, the strands of IBL they practised and how contextual factors influenced their IBL practices were generated as they were of interest to the analyst (Braun & Clarke, 2006).

3.7.1.3 Phase 3: Search for themes

Logically, after coding the data, the third phase is engaged, which is searching for themes. The phase refocuses the analysis at the broader level of themes, rather than codes, and involves sorting the different codes into potential themes and collating them (Braun & Clarke, 2006). After sorting the data that was read from the field notes and analysing the data from semi-structured interviews, the codes were categorically placed into various themes that clearly responded to the research questions the present study sought to answer.

3.7.1.4 Phase 4: Review themes

During this phase, the researcher determines which themes to keep and which are not really themes, and must be removed from the potential themes (Nowell *et al.*, 2017). In this study, after working on the themes, data within the themes were carefully scrutinised. Subsequently, all the themes that did not prove relevant to the present study in the sense that they would not help to answer the research questions, were removed, and those that were relevant were retained. I also realised that data could easily fit into themes because they were predetermined according to the research questions and research objectives. No themes collapsed into others or even into new separate themes there were clear and identifiable distinctions between the themes (Braun & Clarke, 2006).

3.7.1.5 Phase 5: Define and name themes

Braun and Clarke (2006) allude that this phase takes place logically after the themes have been reviewed and a thematic map has been established. After reviewing the themes I defined them and placed relevant data under each theme, which were named according to the research questions. The data in the themes were organised into subthemes and categories to produce thick descriptions of the themes.

3.7.1.6 Phase 6: Produce the report

In this phase 6 I had all the three themes, subthemes and categories that were organised in tables. This was the final analysis and write-up of the report (Braun and Clarke, 2006). The purpose of the theme was to present a logical discussion of data in was that helped respond to the research questions of the study and the discussion culminated in the write up of findings of the study. Furthermore, during this phase, the contexts from which data were collected were described and a sound analysis and discussion of the collected data produced.

3.7.2 Trustworthiness

According to Shenton (2004), qualitative research uses the concept of trustworthiness, instead of validity and reliability that are used in quantitative studies. He subscribes to Guba's constructs and describes credibility, transferability, dependability and conformability as the central criteria addressing trustworthiness (Shenton, 2004). Interestingly, Gunawan (2015) argues that a qualitative study is only trustworthy when the reader considers it to be trustworthy; Gunawan also subscribes to the four criteria discussed in Shenton (2004). Being a qualitative study, the present study ensured the trustworthiness of the research from the time data were collected, to where it was thematically analysed, and I also subscribed to the four criteria of trustworthiness.

3.7.2.1 Credibility

Shenton (2004) states that credibility deals with the question, how congruent are the findings with reality? In the present study, credibility was ensured by adopting the data collection methods that had been used in research projects of similar forms, and using semi-structured interviews and non-participant observation to ensure triangulation, which helped to yield data that are entirely representative of the real-life context in which IBL is implemented effectively in life sciences classrooms (Shenton, 2004; Nowell *et al*., 2017). Shenton (2004) posits that "triangulations may involve the use of various methods, especially observation, focus groups and individual interviews, which form the major collection strategies for much qualitative research".

All the data collection methods that were used enabled an immersion into the context of the phenomenon as I observed the lesson presentations and interviewed the life sciences teachers. After transcribing the data I had collected, the participants were given the transcripts as a method of member checking, allowing them to ensure that the collected data had not been tampered with and were not affected by researcher bias (Nowell *et al*., 2017). Student colleagues and other academics familiar with qualitative research also assisted by commenting, as a way of ensuring peer debriefing; data collection was conducted for two months to ensure prolonged engagement (Shenton, 2004).

3.7.2.2 Transferability

Nowell *et al.* (2017:69) report that external validity refers to the extent to which the findings in a study can be generalised to other contexts, implying that the results of the work at hand can be applied to a wider population. In qualitative research, a study focuses on a smaller environment and a limited number of individuals, so, it is impossible to generalise the results to other situations. However, if readers find the environment in the study at hand similar to theirs, they may consider the findings relevant to their situation. Nowell *et al.* (2017:69) argue that this can be seen as transferability, and posit that it is the reader who can recognise the transferability of the findings, because the researcher may be familiar only with his/her own context.

To ensure transferability of the present study, a detailed description of the contexts from which data were collected is provided, so that readers can understand the contexts and can compare the relativity of the research's contextual factors with their own contextual factors, and make the transfer. The phenomenon under study, which is the practice of IBL in life sciences, is also clearly described in the context of the study, to enable the readers to make comparisons with the practices of teaching methodology in their own contexts (Shenton, 2004:67; Nowell *et al.*, 2017:69). The study conformed to the work of

Maree (2014:19), who identifies key factors for ensuring that the results are transferable:

- The number of organisations taking part in the study and where they are based: In the present study it was clearly stipulated that I would interview and observe four life sciences teachers.
- Any restrictions on the type of people who contributed data: The teachers who were sampled by the present study are strictly teachers who teach life sciences and practice various forms of IBL.
- The numbers of participants involved in the fieldwork: Four life sciences educators were selected as participants in the present study.
- The data collection methods that were employed: In the first part of this chapter, I clearly outlined and explained the various data collection methods applicable to qualitative research that I would employ. Semi-structured interviews, non-participant observation and document analysis were the data collection methods I planned to use for the study.
- The number and length of data collection sessions: One lesson observation, following an interview session, was administered for each of the four participant teachers.
- The time over which data were collected: In this study, the period was two months, which also helped to provide credibility to the study findings.

3.7.2.3 Dependability

Dependability refers to the stability of the findings over time and involves participants' evaluation of the findings, and interpretation and recommendations of the study, so that all findings are supported by the data received from the participants in the study (Korstjens & Moser, 2018). Quantitative researchers use the term *reliability* for their studies, which implies that, if a study is repeated, it would yield the same results. In turn, qualitative researchers use the term *dependability*. In order to achieve dependability, a qualitative study should show a great degree of confirmability, which implies that one needs confirmability to achieve dependability (Ali & Yusuf, 2012; Korstjens & Moser, 2018; Nowell *et al.*, 2017).

In the present study, all the processes and phases of the research are explained. A clear explanation of the research methodology choices, such as the paradigm, is provided, and it clearly states and describes how interpretivism is applicable to the study. An explanation is given of how the study followed a case study research design and qualitative research methodology. Furthermore, I explain how data was collected using semi-structured interviews and non-participant observation. Thematic data analysis is also precisely described. Such a detailed and in-depth methodological description, which Nowell *et al.* (2017) refer to as an audit trail, enables other researchers to undertake similar studies with the possibility of producing similar findings.

3.7.2.4 Confirmability

Moon, Brewer, Januchowski-Hartley, Adams and Blackman (2016) posit that confirmability in qualitative studies is an indication that the findings of a study are a function solely of the respondents and conditions of the inquiry, and not of the biases, motivations, interests, or perspectives of the researcher. Similarly, Korstjens and Moser (2018) postulate that confirmability is concerned with establishing that data and findings are not just figments of the inquirer's imagination, but clearly derived from the data.

To achieve confirmability in this study, qualitative research data collection methods were used, which are described clearly. Purposive sampling was used as a sampling method and it is indicated that that data was collected by observing lesson presentations by life sciences educators, and by administering semi-structured interviews with the educators to gather the necessary and relevant data, which provide evidence that the reported findings are entirely derived from the data I collected from the participants – the sampled life sciences educators.

3.8. PILOT STUDY

Malmqvist, Hellberg, Mollas, Rose and Shelvin (2019:5) propound that "novice researchers, having conducted a pilot study will be better informed and prepared to face the challenges that are likely to arise in the substantive study and more confident in the instruments to be used in data collection". Fraser, Fahlman, Arscott and Guillot (2018:263) posit that "pilot studies help researchers identify design flaws, refine data collection and analysis plans, and to test the efficacy of the data collection instruments". Pilot studies are undertaken to assist researchers to identify potential risks of proposed research and enable them to effect the necessary changes to their research methodology (Malmqvist *et al.,* 2019; Fraser *et al.,* 2018). In this study, the purpose of the pilot study was to test the relevance and efficacy of the designed interview schedule and the observation protocol, and to determine if the instruments would be able to elicit the intended data that would sufficiently respond to the research questions.

I purposively selected a life sciences teacher from an African rural school after being informed by word of mouth during discussions with life sciences teachers in my circuit. A teacher from my neighbourhood informed me that this teacher worked at a school with a laboratory and that he practised IBL. He had been teaching life sciences for four years to Grades 10 to 12. I submitted a letter requesting permission to conduct a pilot study to the school's principal, who summoned the life sciences teacher, who read the letter and agreed to participate. A date was agreed on for an interview session and for the proposed one-hour interview, which eventually lasted 34 minutes, and it was audio recorded. A date was set after the interview for observing the teacher conducting an IBL-inclined lesson. The lesson, during which I observed the teacher conducting a practical investigation with an overcrowded classroom of 57 learners, was audio recorded.

The data generated during the pilot study gave me confidence, as a novice researcher, because the interview schedule for semi-structured interviews and the observation protocol were able to elicit data that responded to my three secondary research questions. The pilot also assisted me by revealing that I had to improve my probing skills to ensure that rich data would be generated through the research instruments. Based on the efficacy of the instruments in generating relevant data, I opted not to change the instruments. As a result, I decided to include the data I had collected during the pilot study in the analysis of data, which will be presented in Chapter 4, because it had significant data that described the perceptions, the strands of IBL used by life sciences teachers and the contextual factors that influence teachers' IBL practices.

3.9. ETHICAL CONSIDERATIONS

Fouka and Mantzorou (2011:3) posit that,

> *the concept of ethical issues in research derives from a branch of philosophy, which is ethics, dealing with the dynamics of decision making concerning what is right and wrong. It implies that research, whether quantitative or qualitative, should be conducted in an ethical manner.*

In the present study, all the participants were assured that participation would be voluntary and would only proceed with their consent. I applied to the ethics committee of the University of the Free State to ensure that all the ethical issues were addressed by the study. The letter granting ethical clearance from the University of the Free State is attached as appendix G.

3.9.1 Harm or risk and mitigation

Participants were informed of any harm or risks the project might cause to them. The nature of the study was explained, so that the participants were in a position to realise when there was a possibility of harm during their participation. It is stated that the researcher should ensure that the participants understood the nature of the study, so that they understood all possible harm and risks (Fouka & Mantzorou, 2011).

3.9.2 Informed consent or assent

Informed consent is the most important principle under ethical considerations, because no participant may feel obliged to participate in a study. The participants should feel that their rights are being respected and that participation is not obligation. Escobedo *et al.* (2007:47) state that, “informed consent is a vital step to any research project”. The participants should understand the whole project and the risks involved, and then it is up to them to decide whether they want to participate. In the present study, the participating teachers were afforded the opportunity to give their written consent before taking part in the study.

3.9.3 Confidentiality and anonymity

The life sciences teachers who participated in the study were assured that their rights to confidentiality and anonymity would be upheld. I used pseudonyms to refer to the educators – no real names were used – to ensure confidentiality. All the data collected were kept confidential and the names of the participants are not divulged, to ensure anonymity (Escobedo *et al*., 2007).

3.10. LIMITATIONS AND DELIMITATIONS

The study subscribed to the qualitative research design and, as a result, the findings cannot be generalised to a larger population, because they are unique to the participants and the contexts in which the study was conducted; the number of participants sampled was quite small.

Rhaman (2017) posits that “qualitative research is a long hard road, with elusive data on one side and stringent requirements for analysis on the other”, which implies that a considerable amount of time is required to conduct the study. Parke and Griffiths (2008) postulate that data collected through observation are sometimes influenced by a high degree of subjectivity, because the researcher serves as the instrument of data collection, which subjects data to the personal biases of the inquirer. To counter this flaw, semi-structured interviews and document analysis were used to triangulate the data and to minimise bias that could possibly come with observation data. Since the researcher is also a life sciences teacher, there would always be a risk of researcher influences on the findings, due to personal bias, which could possibly impinge on the findings. To minimise such influence, credibility, transferability, dependability and confirmability were ensured.

3.11. SUMMARY OF THE CHAPTER

It is important to have a detailed, clear and achievable plan when conducting research, and even then challenges may be encountered. It is the responsibility of the researcher to ensure that the integrity of the research is protected, thereby the trustworthiness of the inquiry in qualitative research is ensured.

This chapter presented the plans used to execute the study, including the research paradigm, which was interpretivism, the research design, which was case study, and the research methodology, which was qualitative research. Furthermore, the chapter discussed the data collection methods, which were explained in detail; thematic data analysis was also explained, as the data analysis method. A detailed discussion of how trustworthiness was ensured in the study was also presented in this chapter, which culminated with a brief explanation of ethical considerations that were applied. The following chapter will present the collected data and its analysis.

CHAPTER 4: PRESENTATION OF FINDINGS

4.1. INTRODUCTION

This chapter will present the findings of this study. Efforts were made to give detailed descriptions of the data collected through semi-structured interviews and non-participant observation. Findings are presented as themes that were predetermined according to the three sub-questions in the study, and which describe how teachers practice IBL in the teaching of life sciences, by closely interrogating their perceptions of IBL, the forms of inquiry they employ in their classroom practices, and the contextual factors that influence their practice of IBL. Semi-structured interviews were used as the main data collection method and triangulation was sought through non-participant observation.

The study sought to answer the following main research question:

> How is IBL practised in life sciences classrooms?

To generate data that would best answer the main research question, three more secondary research questions were answered by the study.

1. How do life sciences teachers perceive the use of IBL in life sciences classrooms?
2. What strands of inquiry are currently practiced in the teaching of life sciences?
3. How do contextual factors influence the practice of IBL in the teaching of life sciences?

These are the themes in the study:

- (i) Theme 1: Teachers' perceptions of using IBL in life sciences classrooms
- (ii) Theme 2: Strands of inquiry practiced in the teaching of life sciences
- (iii) Theme 3: Contextual factors influencing the practice of IBL in teaching life sciences

The themes were subdivided into subthemes and categories in an attempt to provide a thick description of the findings. The main data source was the participants' responses during the semi-structured interviews, which allowed for verbatim quotations in presenting the findings, so as to provide the reader with a first-hand experience of the findings. For the purpose of triangulation, non-participant observations were carried out and the findings, which provide insight into how life sciences teachers practice IBL versus what they provided as responses during the interview sessions, will also be presented in this chapter.

Chapter 3 explicitly explained that four life sciences teachers from three different schools with different contexts were participants, who are identified by pseudonyms, in the study. The schools were deliberately categorised as a former Model C high school, a township public high school, and a rural high school. Incorporated into the explanation of the findings of the study will be a description of the contexts of the three schools where the participating teachers were teaching life sciences. Tables will be used to summarise the themes, subthemes and categories. Table 4.1 presents a summary of the themes, subthemes and categories of the whole chapter. However, each theme is also summarised in a separate table.

4.2. THE FOUR TEACHERS WHO PARTICIPATED IN THE STUDY

Patience was a 28-year-old black female teacher. She held a Bachelor of Education degree in Further and Education and Training, and had majored in Zulu and biology. She was keen on taking up management responsibilities, and she was studying towards a diploma in management, and aspired to enrol for an Honours degree in the same field. She had been a teacher for seven years, but she had been teaching life sciences between Grades 10 and 11 for five years. She was teaching at an African public township school at the time of data collection. The learners came from various neighbouring sections of the township in which the school is situated.

Henry was a 25-year-old black male teacher. He has a teaching qualification and had majored in biology and physical sciences. He had been a teacher for four years, during which he had been teaching life sciences to grades 10 to 12. He taught at an African school, which is situated in a small residential area that was meant for Eskom employees, a few kilometres away from the town of Standerton. The majority of learners travelled by bus from the surrounding rural areas, with a few from the area itself and from the township in Standerton.

Linda was a 24-year-old white female teacher. She had been teaching at a former Model C school for seven months. The subjects she had been offering were life sciences (Grade 12) and natural sciences (Grade 8). She had completed a BSc degree in human physiology, and later gained a Postgraduate Teacher's Certificate in Education (PGCE), which helped her venture into the education fraternity as a life sciences teacher. The school she worked at is situated in town, and served a diverse group of learners regarding race and culture. The learners came from all the areas of the town and were from different socio-economic backgrounds. She advocated a learner-centred teaching philosophy; hence, she practised IBL in teaching natural sciences and life sciences.

Andy was a 28-year-old white female teacher. She had been teaching at a former Model C school for three years at the time of data collection. Her teaching had been focused on life sciences, natural sciences and physical sciences since she started working as a teacher. She had a diploma in early childhood development, a Postgraduate Teachers' Diploma in Education in FET, and B.Com Honours degree in industrial psychology. The participant worked at the same school as participant 3, who had suggested her name because she also practised IBL in teaching life sciences.

4.3. SUMMARY OF THEMES

To provide insight into and to facilitate maximum comprehension of the findings of the study, the themes have been organised into a table. Table 4.1 summarises the themes, to enable the reader to comprehend the findings of the study. The subthemes and categories that were generated during data generation, and which are aimed at providing a detailed explanation of the themes, are also summarised in the tables presented in this chapter.

Table 4.1: Secondary research questions, themes, sub-themes and categories

Secondary research questions, themes, subthemes and categories			
Research questions	**Themes**	**Subthemes**	**Categories**
1. How do life sciences teachers perceive the use of IBL in life sciences classrooms?	**Theme 1:** Teachers' perceptions on the use of IBL in life sciences classrooms	Subtheme 1.1 Perceptions	Category 1: IBL allows for creative thinking
			Category 2: IBL generates learner interest in life sciences
			Category 3: IBL encourages active involvement by learners in the lesson
			Category 4: Interactive learning
2. What strands of inquiry are currently practiced in the teaching of life sciences?	**Theme 2:** Strands of inquiry practiced in the teaching of life sciences	Subtheme 2.1 IBL practical work	Category 1: Linda's guided inquiry
			Category 2: Patience's structured inquiry
			Category 3: Andy's structured inquiry
			Category 4: Henry's structured inquiry
3. How do contextual factors influence the practice of IBL in the teaching of life sciences?	**Theme 3:** Influence of contextual factors in the practice of IBL for teaching life sciences	Subtheme 3.1 School settings	Category 1: School infrastructure

			Category 2: Laboratory equipment
			Category 3: Extracurricular activities
			Category 4: Types of learners
			Category 5: Classroom sizes
		Subtheme 3.2 Policies	Category 1: CAPS
			Category 2: Rigid content
			Category 3: Language of instruction
		Subtheme 3.3 Professional development	Category 1: Teacher training
			Category 2: Content workshops
			Category 3: Discussions with other teachers
			Category 4: Subject advisors

4.4. TEACHER PERCEPTIONS OF INQUIRY-BASED LEARNING

This theme captures and outlines how life sciences teachers perceived and viewed the value of inquiry in their teaching, and their reflection on what inquiry instruction in life sciences classrooms meant to them. The theme concentrates mainly on the positives that accompany IBL in teaching life sciences. Teacher responses to semi-structured interview questions were used to generate the theme. The theme comprises one subtheme: teacher perceptions (1.1), which is divided further into four categories. Table 4.2 summarises the subtheme and the categories.

Table 4.2: Teachers' perceptions of the use of IBL in life sciences classrooms (Theme 1): Inclusion and exclusion data indicators

Theme 1: Teachers' perceptions of the use of IBL in life sciences classrooms		
Subtheme 1: Perceptions	This subtheme focuses on how life sciences teachers perceive IBL and how their perceptions shape their IBL practices	
Categories	**Inclusion indicators**	**Exclusion indicators**
Category 1: IBL allows for creative thinking	This category includes data on teachers' discussions on how IBL promotes creative thinking	This category excludes data on discussions by teachers on other perceptions
Category 2: Generates interest in life sciences	This category includes data on teachers' discussions on how IBL generates learner interest in life sciences	This category excludes data on other perceptions of IBL
Category 3: Active involvement by learners	This category includes data on teachers' discussions on how IBL gets learners' actively involved in lessons	This category excludes data from discussions on other perceptions of IBL
Category 4: Interactive learning	This category includes data on teachers' explanations for how IBL ensures interactive learning by learners	This category excludes data from discussions on other perceptions of IBL

4.4.1 Inquiry-based learning enables learners to think creatively as scientists

Three of the four participants perceived IBL as an instrumental pedagogical approach that affords learners opportunities to think creatively and construct knowledge as they conduct practical activities, just as real scientists do. These participants are Henry, Patience and Linda, who advocated teaching life sciences following inquiry-based approaches. With this approach to learning, learners do not only think within the confines of pre-existing knowledge as outlined by textbooks, instead, they are afforded opportunities to think scientifically and creatively to construct their own valuable knowledge. Linda's perception of IBL suggests that she construed it as effective for developing critical, creatively thinking learners, just as scientists who use the scientific method to generate knowledge think. She reflected on her views of what IBL meant to her own classroom practices as a life sciences teacher:

> *Yes. A lot of things are already there, you have an answer for that, there is theory, they have already been proven but there is still space for people to think more differently and more creatively. What I'm trying to say is that learners can still work in those small groups and think innovatively, in ways that can make them discover new things.*

Even though she did not give a precise description of the steps followed during knowledge construction using the scientific method, she believed strongly that IBL exposes learners to the scientific method. She explained that, when learners work in groups on a given practical activity or any given scientific investigation activity, they are given an opportunity to think creatively, following the steps scientists follow and using the scientific method. In trying to describe the scientific method, she said the following:

> *For me it is to think scientifically. It's hard to explain. All the steps of the scientific method. How they think; how they look at the problem and how they approach it. That's actually the method that scientists use to get us the scientific knowledge we have published to us and the learners.*

Henry’s inquiry lessons were mostly in the form of practical work. He believed in organising learners into groups, after which he explained to them the procedure to be followed during the investigation. Thereafter, the learners worked together in the investigation, guided by the teacher’s procedure. However, the learners were allowed to innovatively design their own alternative procedures to find the solution and answers to the question. Henry explained that learners help one another in the small groups they work in when they try to explain the procedure to one another. The acts of reworking the procedure and helping one another throughout the practical activity evoked creative thinking, thereby preparing learners for and affording learners opportunities to apply the scientific method. In explaining his views on how creative thinking is stimulated during IBL practical investigations, Henry said:

> *Because learners learn better from their peers and there is creative thinking whereby they can manoeuvre and manipulate the situation to come up with, alternatively, a simpler method to explain to their peers so that they can grasp that information.*

Patience also held strong views and perceptions about inquiry lessons being characterised by ongoing processes of creative thinking. Her perception was that, to administer inquiry-based pedagogy, learners should be grouped so that they can mutually interact while working towards a common goal. Among other things, learners share their ideas about the hypotheses they propose for a given practical investigation. In the process, they think critically in coming up with ideas, and try to work towards formulating their hypotheses, which will be followed by the group. She regarded IBL as being instrumental in enabling learners think creatively; she also believed that whole-group discussions play a role in stimulating creative thinking while members work to find answers. In explaining why she perceived IBL as effective in stimulating creative thinking, she said,

> *This enables one to unlock their potential in doing well for the success of the group. IBL enables learners to think creatively as they would each want to*

come up with their own potential hypotheses and each try to prove that theirs is correct.

Furthermore, Patience indicated in her response that the kinds of creative thinking her inquiry activities stimulated are aligned with the scientific method. Like Linda, she was not able to elaborate on and give a pertinent description of what she meant by thinking scientifically, by which she implicitly meant the scientific method popularly utilised by scientists to construct knowledge. When she was requested to elaborate on her meaning of thinking and working scientifically during a practical investigation, she argued briefly,

Scientific thinking involves analysis before conclusion, as members of a group work together they each get a chance to analyse the investigation in their own perspective and then work out a suitable conclusion, which affords each member a chance to think creatively.

4.4.2 Interactive learning

The four participant teachers valued IBL and hailed it for being effective in eliciting interactive learning among learners. The teachers were all able to promote interactive learning because they all believed in and held the ideology that inquiry lessons are administered best through groupwork. In grouping the learners, the participating teachers' ways of practising IBL ensured that learners each took part in the steps of practical investigations, thereby ensuring that learners made a positive contribution to constructing the knowledge they needed to achieve the results they anticipated. As one of the reasons she used to explain why she regarded IBL as being significant for teaching life sciences, Linda said,

I give them an opportunity to work in groups and give and allow them to discuss their findings to compare them with other groups' findings. By so doing, learners acquire skills to interact with their peers in the group and even discussing the findings with other learners in other groups.

Amid positive reflections on Linda's perception of what IBL can offer in terms of enabling learners interact with one another, Andy held similar views, namely that it creates a positive platform for learners to learn by interacting with one another, which she called interactive learning. She explained that learners work best during inquiry groupwork, because they exchange ideas with their peers and maximise their own learning. Furthermore, learners tend to learn best in such situations because they explain the work at their own level and understand it better than when they receive only instruction from the teacher.

> *So interactive learning means I can interact with my friends and learn. Sometimes when they don't understand they ask their friends because learners tend to explain the work at their own level.*

Henry valued and viewed IBL as being a way of unleashing and maximising learning through learner interactions during groupwork that learners carry out during inquiry-based scientific investigations. Like Andy, he believed that learners learn better from their peers than from their teachers. In addition to the academic benefits that accompany inquiry-based pedagogical activities, learners develop sound interpersonal skills as they interact with their peers in their groups. The skills benefit them, as they will need these skills in the workplace one day. In explaining what he considered IBL to be, Henry stated that IBL engages learners in interactive learning in the following ways:

> *Of course there is a value for that. The way I do it, learners work in groups and that to me means they get a chance to collaborate with other members. You know, when they work together in those small groups they help one another and develop interpersonal skills. It is easier for some learners to understand the work when it is explained in those small group discussions by their peers than when we do it as teachers.*

4.4.3 Inquiry-based learning as a way of ensuring active learner involvement

Two of the four participant teachers perceived IBL as being instrumental in ensuring that learners take an active part in their learning. Their views corroborate the discussion in Haury (1993), who describes inquiry-oriented science instruction as being characterised by active learner involvement, hands-on activities and a discovery approach, which underlie the scientific method. They held an ideology that learning life sciences is not optimal in a situation in which the teacher employs traditional pedagogical methods characterised by the teacher predominantly taking a more active role. In the latter, the teacher is regarded as the only one who can impart knowledge to the learners. When she had to expound on why she valued IBL in her teaching practice, Patience stated that IBL lessons are characterised by the active involvement of learners. This, in her opinion, assists learners to construct their own knowledge, which they will own:

> *Yes, it is because it helps learners to be involved in the lesson rather than sitting back to receive knowledge from the teacher and this makes sure that they are into life sciences. In this way, they are able to create knowledge they will own.*

Henry had a similar way of thinking, and argued that, since his IBL practices were mostly in the form of practical work, learners understand when they do practical work. He explained that IBL has a way to elicit maximum learning, because such activities ensure that learners are actively involved in lessons. Like Patience, he compared lessons in which learners are actively involved with lessons that are characterised by traditional pedagogical methods dominated by teachers. Explaining the significance of IBL regarding learning, Henry said,

> *It helps because the learners get to understand the content better when they are doing something practically. This means they are actively involved in the lesson. You know, some learners just get lost when they are taught in a traditional way where the teacher simply teaches without involving the learners to do something.*

4.4.4 Inquiry-based learning generates learner interest in life sciences

It is well documented that the teaching of life sciences currently faces a myriad of challenges all over the world, including a lack of student enthusiasm for and interest in learning the subject (Moore, 2013). In the present study, two of the four participant life sciences teachers perceived IBL as being instrumental in generating learner interest in the subject, since it is not feasible to teach learners a subject they are not interested in. Patience explained that, by engaging learners in scientific investigation activities that are inquiry-inclined, learners were afforded opportunities to realise the links between life sciences and everyday life experiences. Such understandings create a foundation for the learners to develop an interest in learning life sciences, and

> *also makes them to have interest in life sciences because learners sometimes think life sciences content is not relevant to everyday life experiences and easily get to lose interest in the subject.*

She argued further that, when learners engage in scientific activities through IBL, a desire to learn life sciences is stimulated:

> *Apart from creative thinking, when learners do scientific investigations they develop a sense of eagerness and they start to like life sciences. You know sometimes learners just don't like life sciences because they don't know how it fits into their lives.*

Andy held similar views regarding how she perceived IBL and its benefits for her practice as a life sciences teacher. She explained that learners construct knowledge optimally and understand content through visual stimulation. The visual stimulation, subsequently, has a way of generating interest in learners learning life sciences. In explaining her views of what she considered IBL to be, with reference to her own practice, she pointed out,

> *Visual stimulation for the learners is very important as well, which then stimulates and generates interest in them to the learn life sciences.*

4.5. STRANDS OF INQUIRY-BASED LEARNING USED BY LIFE SCIENCES TEACHERS

This theme explores the forms of inquiry practiced by life sciences teachers. A subtheme emerged as IBL practical work. The subtheme is divided further into four categories that are summarised in Table 4.3. Data to explicate the theme were generated through semi-structured interviews, and triangulation was done through observations.

Table 4.3: Observed strands of IBL in life sciences classrooms (Themes): Inclusion and exclusion data indicators for Theme 2

Theme 2: Strands of IBL in life sciences classrooms		
Sub-theme 1: IBL practical work	**This sub-theme focuses on the forms of IBL as practical work in life sciences classrooms**	
Category 1: Linda's structured inquiry	This category includes data on the form of guided inquiry used by Linda	This category excludes data on other forms of inquiry practised in the life sciences classrooms
Category 2: Patience's structured inquiry	This category includes data on Patience's structured inquiry	This category excludes data on other strands of inquiry employed by other life sciences teachers
Category 3: Andy's structured inquiry	This category includes data on Andy's form of structured inquiry	This category excludes data on other strands of inquiry used by other life sciences teachers
Category 4: Henry's structured inquiry	This category includes data on Henry's form of structured inquiry	This category excludes data on other strands of inquiry used by other life sciences teachers

4.5.1 Inquiry-based learning as practical work

4.5.1.1 Linda's structured inquiry

Linda's IBL took the form of practical work that took place specifically in the laboratory. She relished working at a school that was perfectly equipped with favourable contextual factors for her practice. These factors included the presence of laboratories, adequate laboratory equipment, the presence of more experienced teachers and discussions with other life sciences and physical sciences teachers. Adding to the advantageous contextual factors was her exposure to sufficient training she had received while studying for her Bachelor of Science in human physiology. She stated that she had been intensively exposed to laboratory activities, which developed a belief in teaching using laboratory activities in her practice as a life sciences teacher.

This is how Linda described the relevance of the professional development she had received during her undergraduate study for preparing her to conduct laboratory-based IBL:

> *I think, I don't know exactly, but I think if I had just studied BA I wouldn't have been that exposed to life sciences the way I was with the BSc in physiology. So, I have been exposed to a lot different types of things with dissections. I did it physically. I did all the practicals myself and that helps me a lot with my current practice.*

Her advocacy of laboratory-based IBL practical work was also reflected in her explicit indication that she was interested in laboratory work. She was willing to instil the interest in laboratory work in her learners. Her description of the form of IBL as practical work she practiced showed that she neither welcomed nor believed other possible forms of improvisation could be as effective.

This is what Linda said when she emphasised her desire to work with and involve learners in laboratory-based IBL as practical work:

I am very fascinated by the laboratory work and I want that fascination to be welcomed by learners. I want to show them these things, not just show them a video or show them, 'this is the picture', I don't like that. I like them seeing the things.

Linda's IBL resonated with the basic tenets of scaffolded inquiry, in that both parties – the teacher and learners – had roles during scientific investigation activities, with the teacher providing a more supportive role. Furthermore, after a research question had been posed by the teacher, learners used a procedure given by the teacher to conduct the investigation. Based on these aspects, I construed her IBL practice as structured inquiry. The teacher assumed a supportive role and learners engaged in hands-on activities in groups, by engaging practically in all the steps of inquiry. She stated the aim of the anticipated scientific investigation to the learners who, then, worked to formulate the aim of the investigation. Learners were given the apparatus they should use to conduct the investigation. In her description of what she regarded as her strain of IBL, she emphasised the supportive role she assumed and the more active role learners played during scientific investigations:

I give them the aim; they have to identify the variables. They have to convert the aim into a hypothesis. I help them to formulate a research question. I also give them the apparatus they should use in the investigation. I show them one thing and they have to do the rest.

The learners did not have the autonomy to decide on the procedure to carry out the scientific investigation at hand. Linda described herself as a facilitator during the activity. This suggested that, in my opinion, she did not assume the traditional role of a teacher who told the learners everything. She availed herself only when learners needed clarity, by posing questions. This is what she said when she described the roles of the leaners and the teacher in deciding on the procedure for the scientific investigation:

I only see myself there as a facilitator, not a teacher. I'm there to help you and you do the rest. They decide on the procedure on their own.

She emphasised her facilitator role during the activities, by indicating that she did not give any form of answers to the learners. They were always expected to work independently towards the findings and the solution. However, she clung to the basic tenets of scaffolded inquiry by being present for explanations when learners were in need, to give the necessary assistance:

> *During the investigation I'm there to answer questions but don't ask me what the hypothesis is because I have already told you what it is. But if they struggle with a word or something, I help them with that but I never give them the answers.*

Learners worked in groups, following the procedure designed for them. She allowed them to discuss within their respective groups during each phase of the scientific investigation. Subsequently, the groups communicated their findings to other groups by engaging in class discussions. She succinctly described the role she assumes and the activity the learners engage in as they communicate their findings with other groups, in the following way:

> *There I guide them regarding the aim. And then I facilitate the whole thing to ensure it takes the right direction. I give them an opportunity to work in groups and give them an opportunity to discuss their findings to compare them with other groups' findings.*

Observing Linda's IBL practices

The responses generated during Linda's interview corroborated her classroom practice, which was confirmed during observation of her lesson presentation. I observed Linda's lesson presentation, during which she introduced a topic about water to Grade 10 life sciences learners. In her introduction, she told the learners they would be divided into groups of four members each and each group would be given differently coloured clay to represent different types of elements. She wrote the equation showing how a water molecule is formed: $2H+O_2 = 2H_20$. Subsequently, she explained that water is an important resource without which life would not be possible. She made some exchanges with her learners, which suggested an inquiry-inclined lesson:

Linda: Why do you think water is biologically important?

Learner A: We use water every day for things like washing, cooking and cleaning.

Linda: That's correct, but remember we are only interested in the biological functions of water, not just the social uses.

Learner B: (Reading from a book) All chemical reactions take place in the presence of water and breaks down food during digestion…

Linda: Yes! Well, water forms about 75% of our bodies. It is a medium in which all metabolic reactions occur … Just imagine what would happen in our bodies without water. Any other function of water?

Learner C:It transports substances in our bodies … Things like food and metabolic wastes are transported inside our bodies because there is water.

Several other learners stated various points, most of which were read from the book, about how water is important to life.

Linda: Now that we have an idea of what makes water important, I want you to show how it is formed from elements … You'll remember that two hydrogen elements chemically bond with an oxygen element to form a water molecule, which is a chemical reaction.

Corroborating the description she gave during the interview, Linda stated the aim of the investigation to the learners as she explained that they would be investigating how chemical reactions take place. She explained, furthermore, that the example of a chemical reaction they would investigate was the formation of a water molecule from hydrogen and oxygen. Confirming what she had said in the interview, Linda explicitly presented the investigative question and gave the learners a possible hypothesis.

In the interview, Linda said that, following the investigative question and the formulated hypothesis, she would give them a procedure they would follow to conduct the investigation. This was confirmed during the lesson, as the learners were inactive regarding the determination of the procedure, but the teacher categorically explained how the learners would use differently coloured clay to simulate the formation of a water molecule. As the teacher, she allowed learners to work in their respective groups and assisted those who sought help. She moved around the classroom and asked a few questions to the members of one of the group:,

> *Linda: Why are you forming two balls with red clay and only one white coloured clay ball?*
>
> *Learner D: (sighing) it is because there are always two hydrogen atoms and only one oxygen atom that are joined to form a water molecule*
>
> *Linda: Exactly!*

The lesson was in the last period on a day Linda had said was a sports day. It was, therefore, a 30-minute period and her lesson lasted for about 27 minutes. Nothing was done by the members of the groups to discuss their findings with the other groups in the class, which was possibly caused by time limitations. Linda ordered the learners to move back to their original seats and gave them question papers, saying they should write in their activity exercise book, an activity they would complete the following day.

4.5.1.2 Patience's structured inquiry

Patience advocated for and practiced IBL mainly in the form of practical work. In her description of IBL activities, it was evident that most of the scientific investigations she conducted were in the form of groupwork. She provided learners with all the required apparatus. Her description of how she practiced IBL with her learners implicitly revealed that she sometimes encountered situations in which she had to conduct scientific investigations with inadequate materials. Consequently, she distinguished between the forms of IBL activities she conducted: those for which she grouped learners to work collaboratively and those for which she let them work individually. She emphasised, however, that if learners had to engage in an activity in which they applied their observation skills, she grouped them as follows:

> *I go through the specific investigation and ensure that all required equipment is enough for the learners. If there is not enough, I group them so that they can share. And I normally allow them to work in groups for such activities. Sometimes I say, 'just do it individually', especially where they have to read and interpret data. But if it's something they have to do and make observations; I make them work in groups.*

The nature of inquiry that Patience practiced was a more structured type, because learners were given the research question and procedures to conduct the investigation by the teacher. She emphasised, furthermore, that she worked with the learners from the onset and guided them towards formulating the investigative question. She did not give learners the autonomy to decide on their own investigative questions; she was the one who provided the questions to the learners. She succinctly explained how the investigative question should be formulated, as follows:

> *The question will be based on what has been taught. So if we are to do an investigation on a certain topic, what question can we ask? Yeah, drawing questions from what has been taught. And I am the one who poses the question.*

Furthermore, she stated that the learners were given the autonomy to formulate their own hypothesis; they conducted the investigation and made observations. Subsequently, the learners drew up conclusions confirming what they had learnt previously, and prepared for classroom discussions to communicate their findings:

> *My role is just to give them guidance and support. They have to be hands-on. They have to formulate the hypothesis with the help of the educator. In drawing up the conclusions, I allow them to draw up the conclusions*

confirming the findings they have learnt about. They write down their findings and discuss them as a whole class. We don't do presentations.

In every explanation she gave, Patience indicated that she was also involved with the learners during scientific investigations. She was able to engage with learners in each step of the investigation, because she allowed them to work in groups. Like she did with the investigative question, she also decided on the procedure the learners should follow during the activities. This aspect of her IBL practice made it a structured inquiry. Learners started working in groups, to the point where they drew up their conclusions. After each group had concluded the investigation, they were given an opportunity to communicate their findings with the other groups. She specifically identified whole-class discussions as the way learners communicated their findings to the other groups, which she also facilitated. This is what she said in describing how the learners worked together to reach the conclusion, and how they communicated their findings:

I tell them we are going to have an investigation and group them. We go through the investigation to ensure that each step is followed to the letter. I give them the procedure they should follow during the activity. We do each step together during the investigation. After the investigation I ensure they concluded correctly and find out what they have learnt from the investigation. I engage them in class discussion by asking them questions as to what they have learnt. I ask them if they can relate what they learnt in class to what they were doing in the investigation.

Patience emphasised that she was present during the activities to offer guidance and assistance to the learners. However, she gave a contradictory statement, stating that they sometimes worked on their own when the investigation did not involve dangerous chemicals:

I ensure that they follow the instructions. Though I do not tell them, 'do this, do that'. When the instructions are written they must be able to follow the instructions to the letter. I ask them if there is any assistance they need and *we go through the steps together. Sometimes you let them do on their own, especially if there are no dangerous chemicals, then you allow them to work.*

Observing Patience's IBL practice

In the lesson presentation I observed, Patience taught Grade 10 learners to conduct a scientific investigation. She introduced the lesson and subsequently informed the learners that they were going to conduct a hands-on practical activity with an aim of investigating the effect of temperature on the action of enzymes. Due to a shortage of apparatus, she had to divide her 44 learners in four groups of 11 members each. She wrote the investigative question on the chalkboard: How does temperature affect the rate of enzyme activity? She then told the learners they needed to formulate a hypothesis, which she regarded as a crucial step after an investigative question had been formulated. Below is an extract of the exchanges between Patience and her learners.

Patience: Okay … before we can proceed with the practical activity, do we still remember what is the meaning of hypothesis?

Learners: Yes ma'am.

Patience: Perfect! Now can we have someone to briefly explain to us the meaning of hypothesis? What is the meaning of the concept in a practical activity?

(Learner A raises her hand)

Patience: Yes … Andiswa?

Learner A: It is a possible explanation or answer to a question Ma'am.

Patience: That's correct! Remember your hypothesis is always in the form of a statement, just the way your conclusion would be written out. What makes it different from your conclusion is that you formulate it before you make an *observation. Now can I have someone to give us an example of a possible hypothesis for our practical?*

Learner B: When temperature increases, the rate of enzyme activity also increases.

Patience: Good. Just remember we can have two more possible hypotheses for this activity. It is possible to have a hypothesis that is negative or one that shows that temperature does not affect the rate of enzyme activity.

The teacher then distributed the apparatus and materials, including differently coloured clay; three 200 ml glass beakers per group; chocolate to stain material; a kettle to boil water; thermometers; three petri dishes per group; a tweezer; biological washing powder; white cotton material; a measuring spoon; tap water and a glass rod. Some apparatus was unavailable; there were insufficient thermometers, glass rods, tweezers and petri dishes for the groups. She subsequently explained the method to be used during the practical investigation to the learners. Each group had three test tubes marked as test tube A (boiling water, stained cloth and washing powder), test tube B (tap water, stained cloth and washing powder) and test tube C (stained cloth and tap water only). Learners were instructed to observe what happened to the cloths in each of the beakers after 15 minutes. While the learners were working on the activity, Patience paced the classroom and made some exchanges with the learners in the groups:

Patience: Now that we set up this apparatus, can you explain why you have different materials in the beakers?

Learner C: We do it to expose the dirty cloth materials to different temperatures Ma'am … to see how temperature will affect the enzyme in the washing powder.

Patience: Great! And why do we put no biological washing powder in test tube C?

Learner D: I think it serves as a control since the factor we are investigating is absent … (with a sigh) to prove the results in test tube B.

Patience: That's right.

The learners were instructed to observe the manner in which the stained material reacted in the three test tubes. The observation showed that, in test tube A, the chocolate stains were partly removed. In test tube B, the stains were almost completely removed, while in test tube C, the stains remained the same. Patience then engaged learners in a class discussion, which she facilitated by posing questions. The exchanges she made with the learners contained some elements of inquiry:

Patience: From your observations, which test tube had evidence of most stain removal?

Learners: Test tube B.

Patience: Can anyone explain why we experienced different results in each test tube?

(A number of learners raised their hands with excitement)

Patience: Yes Vuyo?

Learner E: In test tube A the stain was partly removed, the temperature of the water was too high and the enzymes were denatured. In test tube B the stain was removed because the water gave an optimum temperature for the enzymes. In test tube C the stain was not removed because there was no enzyme … (Other learners applauded)

Patience: That was good!

In the interview, Patience said she is the one who suggests the procedure to the learners, which is exactly what she did during the observed lesson. She assumed a more active role by helping the learners out regarding how they handled the materials and how they should use the equipment while they carried out the investigation. She gave the learners instructions, and guided them regarding the procedure to be used. Learners asked questions when they did not understand the procedure, but they relied entirely on the procedure given to them by the teacher. At the end of the activity, the learners engage in a class discussion, which was facilitated by the teacher posing random questions to the learners regarding what they observed during the activity.

4.5.1.3 Andy's structured inquiry

Andy also advocated practical work as a way of practicing inquiry. From her explanation, it was evident that she practiced structured inquiry. Her emphasis was on letting learners work independently while she was present to provide the necessary guidance when the learners had questions, ensuring scaffolding throughout the phases of the lesson. She gave learners a research question and stated that learners were responsible for formulating their own hypothesis; her role was to explain to them the meaning of hypothesis. She also believed in class discussion as a way learners would communicate their findings with each other. This is how she introduced her inquiry practice:

> *I just provide the information and facilitate the whole thing. So, I don't give them the answers, they have to apply their previous knowledge as well as practical knowledge when they answer the questions. We just guide them through the scientific method; we don't give them the answers. I teach them the correct way of formulating a hypothesis and then allow them to do it and every other step on their own. After the activity is done, I use classroom discussions to let them report back on their findings.*

She emphasised the matter of autonomous learning, after which learners communicated their group findings in the form of class discussions during the inquiry lessons, as follows:

I'm there during the scientific investigation activity. I allow them to work on their own and would come in help show them how to do it when they struggle and once they accustomed with what they have to do the practical starts flowing. I just facilitate it. So if the learners have a specific problem, maybe they've a question they are struggling with, I guide them into thinking how can I answer it. It's the learners' role to apply their knowledge to arriving at the answer. At the end of the investigation, the learners engage in class discussions to report on their findings.

In response to a question on the procedure the learners used, Andy stated that she was the one who decided on the question. She explicitly stated that she guided learners through the procedure they had to follow during the investigation; they were only allowed to work following the procedure she had designed for them:

Okay once again, my role is to give them information on what procedure they should use in conducting the practical and they conduct it using the procedure I have given to them.

Formulating an investigative question was one of the crucial steps of the inquiry process, to get it started. Andy indicated that they normally worked with sets of several questions to answer. The most encompassing question would be treated as a research question and the one from which learners were instructed to formulate an investigative question. It is the learners' responsibility to formulate the question. Describing how an investigative question is formulated, Andy succinctly indicated that it is the learners' responsibility to formulate it, as follows:

They formulate their own question. Remember we give them the experiment with the information and then we say, in our questions, because there are usually up to fourteen questions. In the questions we stipulate, 'give the investigative question, give the aim, give the scientific means', et cetera.

Observing Andy's IBL practice

I observed Andy's Grade 12 life sciences lesson, which was presented in a science laboratory. The laboratory, in my opinion, seemed to be well equipped with various materials that can be used in life sciences teaching and learning. Various models, plant and animal specimens, as well as other laboratory apparatus, were in the laboratory. The lesson was based on an online gaming application called Kahool. The learners were instructed by the teacher to have their handset devices switched on and she gave them a password to connect to the Wi Fi network of the school. She indicated in her introduction that learners would learn about DNA and chromosomes during the lesson. In introducing the lesson, she stated that they would investigate how DNA forms chromosomes, and she informed the learners that their investigative question would be, How does DNA form chromosomes? She then seemed to remind learners what DNA is, as a way of introducing the lesson:

> *Andy: Before we get started with our game, I want us to briefly look at this [pointing to a structure of DNA displayed on the smart board]. You'll remember we have two types of nucleic acids which are DNA and RNA. Can we identify the one displayed here?*
>
> *Learners: DNA.*
>
> *Andy: Exactly … Now tell me. How do you know it is DNA? Remember you can't just say it's DNA without being able to identify visible reasons.*
>
> *Learner A: It is made up of two strands joined by hydrogen bonds.*
>
> *Andy: That was good! Any other reasons?*
>
> *Learner B: It is coiled and a long molecule.*
>
> *Andy: Yes, that's correct.*

Learners, divided into two groups, started working through various questions on the structures of DNA and chromosomes. The game was in the form of a competition that required learners to respond to various questions on DNA and chromosomes. They were divided into two groups and the scores of each group were displayed at the end of each question. Most questions were on how nucleotides pair up to form a double helix DNA and how DNA is the main constituent of a chromosome. Andy then engaged the class in a short question-and-answer session, as a way to determine their understandings of how nucleotides form DNA. The following are a few exchanges between Andy and the learners during the question-and-answer session:

> *Andy: The molecule we are talking about is DNA, which stands for deoxyribonucleic acid. What is the main thing about its components that make it DNA and not RNA?*
>
> *Learner C: I think it's because of type of sugar in it. It has a deoxyribose sugar and not ribose sugar.*
>
> *Andy: Absolutely! Now tell me… What did you observe regarding how DNA is formed from nucleotides? How do nucleotides form DNA?*
>
> *Learner D: DNA is double stranded … it happens because the nucleotides arrange themselves according to complimentary bases.*
>
> *Andy: Can you elaborate on what you mean by complimentary base pairs?*
>
> *Learner D: (with a sigh) We have adenine, which only pairs up with thymine, and guanine only goes with cytosine.*

The lesson corroborated all the aspects Andy had described during the interview. The teacher stated the aim of the activity, which was to explore the structure of DNA and how it forms chromosomes. Learners were placed into groups to discuss the questions the teacher displayed to them. In the activity, they observed diagrams showing structures of DNA and how differently shaped nucleotides come together to form complex molecules of DNA. Learners matched DNA nucleotides according to their complementary base pairs (thymine to adenine; guanine to cytosine). The procedure followed in the activity was determined by the teacher, confirming what she had stated in the interview.

At the end of the lesson, the teacher allowed learners to move back to their original seats. Subsequently, she engaged them in a class discussion, encouraging them to report back to each other.

4.5.1.4 Henry's structured inquiry

Henry believed groupwork was effective for conducting scientific investigations. He stated that he organised learners into groups of five members to ensure that they worked together, which was one of the basic tenets of IBL. The learners were given the procedure that they would use to conduct the scientific investigation. This is how he explained grouping, as the first step in preparing the learners for an investigation. He stated that he gave the procedure to the learners,

> *Before the investigation, firstly I organise learners into groups of a maximum of five members in each group to allow them work together. I explain clearly the method because you cannot conduct a scientific investigation without a clear method.*

Henry was present while the learners worked on the investigation and he provided guidance. He said he explained to them how to go about the steps of the investigation, which prevented them from working towards irrelevant results and spending too much time on a single activity. It is noteworthy that part of the explanation he gave the learners was that he explicitly supported learners regarding the procedure they used during their inquiry activities:

> *Yeah, for myself, I read what the investigation or practical work is about to understand the steps and the methods to be followed so that I can clearly explain to the learners as to how they should go about conducting the investigation. To avoid letting them work towards irrelevant results I guide them throughout the process and wasting too much time.*

The first step through which he guided the learners was the formulation of an investigative scientific question. He said he guided learners through identifying the variables. After identifying the variables, the learners, in their groups, subsequently formulated the investigative question. He emphasised that, even though it was the learners' role to formulate their own investigative questions, he still assisted them to formulate them:

> *Before we can pose the question I tell them that the scientific question should clearly show the variables. I ask them to identify the variables. And then I guide and assist them to formulate the question.*

The steps following the formulation of an investigative question included formulation of a hypothesis, conducting the investigation (which should involve their observations), drawing up a conclusion and communicating the findings. Henry explained the meaning of hypothesis as a concept, and thereafter let learners formulate their own hypotheses. The learners thereafter engaged hands-on in working with the investigation. They made observations from which they drew conclusions. Their findings in each group were communicated to other learners in other groups by engaging in class discussions:

> *I explain the meaning of hypothesis and let them hypothesise on their own. I let them conduct the investigations hands on. The learners conclude on their own. After the activity I engage the learners in a class discussion to make room for them to communicate and report on their findings. That is where I get to draw back to the expectations, telling them as to what was expected of them against whet came as their findings.*

Observing Henry's IBL practice

I observed Henry's lesson presentation, which was a practical investigation with a Grade 10 life sciences class. The lesson took place in a science laboratory with 57 learners. Henry introduced the lesson, informing the learners that they would investigate the effect of temperature on enzyme activity. He then grouped the learners into groups of four members and distributed the materials to be used during the investigation. The learners were guided by the teacher throughout the steps of the investigation, who assisted them to formulate a hypothesis. He wrote the aim of the investigation on the chalkboard as follows: Aim – To find out how temperature affects the rate of enzyme activity. After writing the aim on the chalkboard, Henry explained a few things to the learners. These are the exchanges he made with the learners in their respective groups:

> *Henry: Okay … now that we know what the aim of the investigation is, we can now state our hypotheses, which you cannot do without knowing the aim of the investigation… Can we have a possible hypothesis from anyone?*
>
> *Learner A: An increase in temperature causes an increase in enzyme activity … and, when temperature is low the action of enzymes is also low.*
>
> *Henry: Wonderful! Just remember that in a practical investigation we have only one hypothesis. Landiwe, your group will then be working on one the two hypotheses you presented.*
>
> *(A few learners still had their hands raised)*
>
> *Henry: Yes Musa.*
>
> *Learner B: Temperature has no effect on the action of enzymes.*
>
> *Henry: That was good … Remember there is always more than possible hypothesis in an investigation.*

Henry allowed learners to set up the apparatus according to the instructions he had read to them, after handing out worksheets. He emphasised that each group should have three test tubes marked test tubes A to C. Test tube A had hot water and mud-stained cloth; test tube B had tap water, a mud-stained cloth and an enzyme-containing washing powder, and test tube C had tap water and the mud-stained cloth only, no washing powder. He walked around asking questions to learners in groups. Moving to one of the groups, he engaged in exchanges with the learners:

> *Henry: Why do you think you should not have the washing powder in test tube C?*

Learner C: Ehm … I think it's used as a control Sir …

Henry: That's right … Why is it necessary to have it in an investigation?

Learner D: Sir, if we can have only the experiment as in test tube B; we would not be sure if the results are true. We use the third test tube to confirm the results in the experiment.

After working in the groups, learners were instructed by the teacher to observe what happened in the test tubes. Subsequently, he instructed each group to elect a member to present the observations and their conclusions. Only members of three groups were able to present, due to the time available:

Henry: Alright … We need to talk about our findings. Let us have one person from each group to present the conclusion, which is based on what you observed in the activity.

Learner E: The contents in the test tubes reacted differently … In test tube A the mud was a little bit removed but not completely because the temperature of the water was too hot and caused the enzymes to be denatured. In test tube B the stain was removed because the temperature was optimum for the enzyme and in test tube C it almost stayed the same because it was a control and had no washing powder.

Henry's inquiry practice, I noted as I observed his lesson presentation, had aspects that confirmed the principles of his scaffolded inquiry he had described during the interview. The teacher stated the aim of the investigation to the learners. The learners then worked from the stated aim to formulate their own hypotheses, and designed their investigative questions. The teacher explicitly explained to the learners what they should do to investigate the effect of temperature on enzyme activity (a rise in temperature causes a rise in enzyme activity). All the steps I observed during his lesson were in line with the approach to inquiry he had described in the interview.

However, the manner in which the conclusion was brought about was not consistent with the description in the interview. In the interview, Henry had said that conclusions in his inquiry lesson are in the form of class discussions. In contrast, the learners were instructed to present their findings in front of the class. Each group assigned a member to present the findings and the teacher corrected the leaners when they deviated from his expectations.

4.6. CONTEXTUAL FACTORS INFLUENCING THE PRACTICE OF INQUIRY-BASED LEARNING IN LIFE SCIENCES TEACHING

This theme broadly captures the contextual settings within which life sciences is taught through inquiry pedagogy. It reveals that the practices of life sciences teachers, as they implement IBL, are largely dependent on and influenced by contextual factors. The theme is divided into three subthemes: school settings, policies, and professional development.

The subthemes are divided further into categories that explain the contextual factors precisely and thereby give insight into how they influence life sciences teacher practices of IBL. The subtheme, school settings, is divided into four categories: school infrastructure, laboratory equipment, extracurricular activities, and time constraints. The second subtheme, policies, is divided into CAPS, language of instruction, and rigid content. The third subtheme captures all the activities that contribute to teachers' professional development. The activities are broken down into categories that describe the subtheme. The categories are teacher training, content workshops, discussions with other teachers, teacher in-service practice, and the role of subject advisors.

Table 4.4: Contextual factors that influence the practice of IBL in life sciences classrooms (Themes): Inclusion and exclusion data indicators for Theme 3

Theme 3: Contextual factors that influence the practice of IBL in life sciences teaching		
Subtheme 1: School settings	**This sub-theme focuses on contextual factors that are associated with the school settings**	
Categories	**Inclusion indicators**	**Exclusion indicators**
Category 1: School infrastructure	This category includes data on - teachers' discussions on how school infrastructure enables them to practise IBL - how school infrastructure negatively affects their IBL practice	This category excludes data on discussions by teachers on other contextual factors
Category 2: Laboratory equipment	This category includes data on teachers' discussions on - how the presence of laboratory equipment promotes their IBL practices - how the shortage of laboratory equipment negatively affects their IBL practices	This category excludes data on other contextual factors
Category 3: Time constraints	This category includes data on teachers' discussions on how time constraints challenge their IBL practices	This category excludes data on other contextual factors
Category 4: Types of learners	This category includes data on teachers' discussions on how learners' attitudes influence their IBL practices	This category excludes data on discussions on other contextual factors
Category 5: Classroom sizes	This category includes data on teachers' discussions on how classroom sizes influence their IBL practices	This category excludes data on discussions on other contextual factors

Sub-theme 2: Policies	**This sub-theme focuses on contextual factors that are stipulated by policy**	
Category 1: Stipulated content	This category includes data on teachers' discussions on how the rigid content stipulated for FET life sciences influences their IBL practices	This category excludes data on other contextual factors
Category 2: Language of instruction	This category includes data on teachers' discussions on how the language of instruction affects their practices of IBL	This category excludes data on other contextual factors
Sub-theme 3: Professional development	**This sub-theme includes data on teachers' discussions on professional development**	
Category 1: Teacher training	This category includes data on teachers' discussions on how teacher training has contributed to their IBL practices	This category excludes data on other factors that have to do with professional development and other contextual factors
Category 2: Content workshops	This category includes data on how content workshops help teachers practice IBL in teaching life sciences	This category excludes data on other factors that have to do with professional development and other contextual factors
Category 3: Discussions with other teachers	This category includes data on teachers' discussions on how teachers who are very experienced assist them with their IBL practices	This category excludes data on other factors that have to do with professional development and other contextual factors
Category 4: Teacher in-service practice	This category includes data on teachers' discussions on how their own practices as teachers have enhanced their IBL implementation	This category excludes data on other factors that have to do with professional development and other contextual factors
Category 5: Subject advisors	This category includes data on teachers' discussions on how life sciences subject advisors contribute to enhancing	This category excludes data on other factors that have to do with professional development

	their IBL practices	and other contextual factors

4.6.1 School settings

The four teachers participating in the study reflected on the school settings and how it affected their practices of IBL. Their responses revealed that various contexts of school settings significantly affect practices of IBL in life sciences classrooms. It is noteworthy that the four teachers are from three schools in three different contexts. The categories of settings that have an impact on teacher IBL practices are school infrastructure, laboratory equipment, and time constraints.

4.6.1.1 School infrastructure

In this study, school infrastructure refers mainly to the nature of laboratories and classrooms in which inquiry-based life sciences lessons are conducted. Three of the participants asserted that their schools had laboratories; hence, some of their inquiry activities took place in laboratories, in the form of practical work; they were Linda, Andy and Henry. Ssempala (2017) argues that IBL instruction is influenced by factors such teaching resources, class sizes and limited time for teaching many lessons. The participants in this study were also influenced by some of these factors.

Both Linda and Andy indicated with confidence that they had access to laboratories at their schools. In her reflection on whether the school setting, in terms of infrastructure (the availability of a laboratory), encouraged the practice of IBL, Linda said,

> *The school is actually perfect for it.*

Linda believed that the school she worked at was adequately furnished with the required number of laboratories. She elaborated that she conducted some of her inquiry lessons in the laboratory, of which her school had enough, without stipulating the exact number of laboratories. In explaining how the school's infrastructure influenced her choice of teaching life sciences through scientific inquiry, she said,

> *We have enough laboratories, so yeah; the infrastructure does allow me to do it.*

Andy also valued that she worked at a well-resourced school, particularly with regard to the availability of science laboratories that she had access to. She indicated that her life sciences lessons took place in a classroom. However, inquiry lessons were an exception, because she explicitly indicated that scientific investigation lessons took place in a laboratory, which is why most of her inquiry lessons took the shape of IBL practical work. She stated that her school had two laboratories, which allowed her to conduct inquiry-oriented scientific investigations:

> *We've got two laboratories. Unfortunately my classroom isn't a lab but I can use the labs. When we do practical work we go to the labs that have all the safety equipment.*

The availability of adequate infrastructure at her school enabled Andy to conduct IBL activities with ease. In addition having access to laboratories, she stated that the number of classrooms at the school was sufficient. As a result, the 1:25 teacher-learner ratio in most of her classes was reasonable. This allowed her to work with ease, as her IBL practice required of her to have an ability to move between the tables as she facilitated the learners' work to provide scaffolding. This is how she described the nature of the classrooms:

> *We are advantaged because our school has enough classrooms and the number of learners in our classrooms is quite reasonable and it allows you to easily facilitate the investigative work done by the learners.*

Henry reported that he worked at a school that had a laboratory. However, the frequency of his inquiry lessons was not as high as he would have liked. In explaining the reason for the unsatisfactory frequency of IBL lessons in the laboratory, he lamented the shortage of relevant laboratory apparatus (this is captured in the next category). He explained that, even though the school had a laboratory, the lack of apparatus precluded the effective implementation of IBL:

> *We do have the laboratory, but the equipment is not sufficient.*

Patience's inquiry practices as a life sciences teacher were largely influenced by her school having no laboratory. Though she was interested in doing practical work, she worked at a school that was not privileged in terms of being provided with a laboratory. She bemoaned having to work under such circumstances:

> *And laboratory activities of which we do not have a laboratory at this school.*

Furthermore, she described the kind of classrooms in which life sciences lessons in general, and those that are inquiry-inclined had to take place. These were the same classrooms in which non-science subjects were taught. Consequently, learners did not get the feeling they were doing science. These limitations had a negative impact on her IBL practices, as learners have to feel like scientists during inquiry activities, because they discover knowledge using the same scientific inquiry methods that are employed by scientists in real life.

> *We do not have a lab. In the same classroom where they learn English, that is where they have to learn life sciences and do scientific investigations. So the learners do not get the feeling, 'I'm a scientist now, I'm doing something scientific.'*

4.6.1.2 Laboratory equipment

Findings from the semi-structured interviews that were conducted with the participants reveal that all four participating teachers' IBL practices were influenced by the availability of laboratory equipment and apparatus. Kang and Keinonen (2016) reveal that schools in Finland and Korea lack appropriate teaching material such as science laboratories and digital resources. Similarly, it was revealed in this study that two of the participants, Linda and Andy, worked in contexts that are characterised by the availability of the apparatus and laboratory equipment needed for IBL practices. Adversely, the other two participating teachers, Patience and Henry, revealed that they taught at schools whose contexts were characterised by a shortage of relevant laboratory equipment, including the pertinent apparatus.

Linda and Andy relished working in conditions that were favourable for carrying out scientific investigations and IBL. Consequently, both teachers' IBL practices were characterised by practical work. In expressing satisfaction about working at a school that had enough laboratory equipment, Linda said,

> *I am privileged; I actually thank God I got appointed here.*

Similarly, Andy indicated that the conditions at her school were favourable for effective implementation and practice of IBL, due to having access to sufficient laboratory equipment. She elaborated that she had access to two laboratories that were well equipped. She described the context she worked in as having most of the required laboratory equipment needed to conduct scientific investigations:

> *We've got microscopes, we've got dissecting boards; we are well equipped to teach life sciences.*

It is, however, noteworthy that Andy also indicated that she was sometimes unable to conduct the scientific investigations she would have liked to. She attributed this inability to the CAPS sometimes prescribing scientific investigations that the school lacked equipment for. Under the circumstances, she sometimes found herself in situations where she could not carry out either the investigations she wished to carry out, or some of those that were prescribed by the CAPS. She was disappointed about being unable to conduct some practical activities due to insufficient laboratory equipment:

> *Sometimes CAPS gives practicals we cannot do because our school does not have the equipment to do that but we do them as far as the CAPS says we should do if we have the equipment.*

Henry and Patience both complained about the shortage and, sometimes, the total lack of relevant apparatus for conducting scientific investigations as part of IBL. According to them, the shortage reflected on their IBL practices, and reduced the frequency of IBL activities. Patience said,

> *Sometimes we lack appropriate equipment and apparatus to conduct such activities.*

Even when Patience's school was supplied with the relevant equipment, it was not always enough. Both conditions, insufficient equipment, and a total lack of laboratory equipment, reflected negatively on her IBL practice. Sometimes she had to improvise by resorting to teacher demonstrations, instead of exposing learners to real, hands-on scientific investigations. Sometimes she ended up having to describe the activities to the learners. Resorting to teacher demonstrations and describing scientific investigations is against the basic tenets of scientific inquiry. This is how she described the situation and how the absence of laboratory equipment influenced her IBL practices negatively:

> *You find that some of them you do not have the equipment. So some of them you skip, some of them we theorise them, you see. You end up telling the learners this is what, this is what. I have never done more than what is stipulated because of the reasons stated about above.*

Despite working at a school that has a laboratory, and mostly presenting IBL in the form of practical laboratory work, Henry reflected on factors that influenced his IBL practices negatively. Sometimes the laboratory he had access to did not have a supply of the required equipment or apparatus.

> *Because of the lack of some apparatus in our laboratories, we are told to do some of the practical work verbally and sometimes we give the learners the procedure on how to approach investigative questions and because we a farm school and are under-resourced. It's not always possible to conduct all of the practical investigations.*

4.6.1.3 Time constraints

Three of the participants, Linda, Andy and Henry, indicated that their inquiry practices in teaching life sciences were negatively affected by time constraints. Notably, this factor can be considered together with several other factors that are also explained in this category. Linda stated that, from a general point of view, the life sciences curriculum was congested, with too much content that had to be completed within a short space of time. Consequently, she found it difficult to complete the content within the set timeframes. Sometimes it was not easy to conduct scientific investigations, as they required more time than was available. She gave a general statement indicating that she finds it difficult to complete the stipulated content within the intended time limits.

> *What I have realised is that sometimes as a teacher you struggle to teach the required content and complete it in the intended time frame.*

Furthermore, even though she did not state it explicitly, she indicated that her IBL practices were influenced negatively by a lack of time. Her explanation showed that she conducted scientific investigations with the learners, but she was not at liberty to conduct them as often as she would like to, because of time constraints.

> *I can't conduct them as much as I would like to. I stimulate the learners by using past exam papers but as for telling them to go out and do it; it's something I don't have time for this year. I would have loved to do that. There's no time for me to do this.*

Linda emphasised that she experienced time constraints and did not have enough time for contact sessions with learners. She did not explicitly state the factors that took up much of the time at her disposal for teaching in general, and conducting scientific investigations in particular. However, she suggested she would be able to conduct such activities more frequently if more time could be offered for her to implement IBL optimally. Responding to a question asking what she would need assistance on so that she could carry out IBL activities more frequently, she said:

> *Time. If I can have more time I can do more scientific investigations. I can spend time with the children, but I don't have the time.*

Andy echoed Linda's views. She said that she did not have sufficient time to conduct lessons through inquiry-based pedagogy – neither general activities in the form IBL, nor those that are stipulated by the CAPS. The number of scientific investigations was sometimes influenced by the time that was available:

> *But the time given to us does not suit it. The CAPS is taking up a lot of time.*

She emphasised the issue of the congested curriculum, which results in too little time to conduct scientific investigations. She referred to one term that was characterised by too little time. The school had to be prepared to accommodate a variety of activities, such as teaching to cover the content, writing examinations and conducting practical activities. She stated that this time was not sufficient for scientific investigations to be done, as she had planned.

> *Just due to the fact that the content was a lot and we didn't have enough weeks to get through the content, as well as do the revision, as well do the practicals and then for the kids to write the exams.*

In addition to factors that resulted in time constraints, Andy described her school as a former Model C school. She explained that she was also involved in extracurricular activities that sometimes took up the time she would have used to have contact with learners. She stated that she sometimes had to use her teaching time for extracurricular activities, which implied that contact time with the learners was lost. She explained how these activities affected teaching time, and impacted the time available for IBL scientific investigations:

> *Because also remember in the former Model C schools you've got sports, extracurricular activities, everything like that. And also prevents you on some of the days from being in class and that is where we sometimes lose a lot of theoretical base.*

Henry also referred to the time factor as one of the challenges in his practice of IBL. He stated that he could not conduct all the prescribed scientific investigations. The life sciences FET curriculum was congested with content and teachers had to focus on completing it. As a result, Henry found it challenging to cover the content with the learners and incorporate IBL scientific investigations in his practice. In responding to a question on whether he was able to conduct scientific investigations, at least as frequently as prescribed by the CAPS, he said,

> *I cannot perform all of them due to time constraints. You know, you have to focus on teaching the content and the time frame is always a factor because you have to cover all the content, which is a lot, against set time limits. You end up doing as much as you can.*

4.6.1.4 Types of learners

Three of the four participants, Linda, Andy and Henry, talked about having to teach learners with different intellectual capacities. Linda stated that she had to conduct scientific investigations with intellectually diverse learners: some were above average, some were average and some were below average. The main challenge she experienced was that the below-average learners found it difficult to complete the activities on time and, in my opinion, might have needed more teacher intervention. Explaining the contextual factors that influenced her practice of IBL, this is what Andy said regarding the types of learners she worked with:

> *It is also a challenge that you have learners who are above average, average and below average in the same classroom because the below average are sometimes struggling with the practical work and it may take time to complete a task.*

Andy echoed Linda’s remarks, and elaborated on the below-average learners she taught. She stated that these learners did not understand how to conduct practical work, which affected her IBL practice negatively. As a result, she needed to take more time than envisaged to explain to them and show them how to conduct the investigation. In contrast, her above-average learners tended to understand the work much quicker and could work autonomously on scientific investigations. Explaining how the learners understood and worked on scientific investigations based on their capabilities, Andy said,

> *With the learners, especially the below-average learners, they don't actually understand how to do the practicals. With them we tend to spend time explaining it to them, show them step by step how to do it, whereas your above average learners go on, on their own.*

Henry shared a similar perspective as Linda and Andy. Even though he did not differentiate his learners into below average, average and above average, he distinguished between learners based on their academic abilities. He said there were learners who were quick to understand and those that were slow to understand. He said he sometimes had to spend more time than anticipated explaining the instructions and other parts of the activity:

> *Another challenge will be that learners don't grasp and understand at the same pace. You will have those that are quick to understand and those that will take some time to understand the work, which the means you will have to spend more time explaining the activity to them.*

4.6.1.5 Class size

In a similar study by Samuels and Dudu (2017), life sciences teaching and learning appeared to face a number of challenges. Most life sciences teachers have to teach the subject in overcrowded classrooms. Marais (2016) also argues that overcrowded classrooms remain a challenge in South Africa. In this study, Patience was not an exception, as she reported that she taught large classes in a township public school. She indicated that the numbers in her classes were abnormally high and, as a result, it was difficult to teach IBL-inclined lessons, as she did not even have sufficient space to move around. This situation does not support IBL, because a teacher is a facilitator during activities and has to move around freely to guide and assist learners when necessary:

As a result we have to conduct the scientific investigations in a classroom that is packed with learners. Numbers in our classrooms are not normal. We often conduct lessons in classrooms with more than fifty learners with very little space to move around.

She also pointed out that conducting IBL lessons in an overcrowded class was a quite daunting activity. Other inherent factors are inextricably linked to large classes, such as a shortage of laboratory equipment, because even if the laboratory apparatus for an envisaged scientific activity was available, there would not be enough for this many learners. As a result, learners were discouraged, lost interest in participating and playing a positive role in inquiry-based lessons.

You can only imagine yourself trying to conduct a practical activity with so many learners. That also contributes and leads to other factors such as shortage of apparatus because even if you do have them, they will never be enough for so many learners. And learners may feel discouraged to work in groups in such conditions.

4.6.2 Policies

The current South African curriculum is the CAPS. The policy has been made available to in-service teachers across the FET phase and all the content they teach, and in most instances, how it should be taught, is rigidly stipulated in the document (DBE, 2011). This subtheme, therefore, captures issues relating to what the CAPS stipulates and how it affects life sciences teachers' practice of IBL. The section is divided into two categories: stipulated content and language of instruction.

4.6.2.1 Stipulated content

This category captures the reflections of life sciences teachers regarding the inflexibility of the CAPS, which precludes teachers having the autonomy to select content. Andy, for instance, said that some parts of the content required irrelevant practical investigations to be carried out. She said they could only teach what the curriculum approved – life sciences teachers were not permitted to make any changes .

> *Sometimes I feel like we are pressed to do practical investigations that do not make sense. For example, if we are busy with a certain topic, there's an investigation about it that doesn't make sense with regard to the topic. We were busy the previous times with the root and stem, but we were told do an investigation on enzymes. We did that, it was fantastic, but it was not relevant.*

Linda reported she worked with a rigidly prescribed curriculum. One of the challenges caused by following such a rigidly articulated curriculum is that the curriculum is congested with content, and teachers are sometimes confronted by a lack of time. Linda argued that, despite access to laboratories and adequate laboratory equipment, the time factor did not always allow inquiry activities to take place:

> *The CAPS has a lot of content and it does not allow you to do as much scientific investigations as you would like.*

4.6.2.2 Language of instruction

In most South African high schools, life sciences is offered in English, and in Afrikaans in some schools. As a science subject, it includes a wide range of scientific concepts. Two participant teachers (Henry and Patience) stated that their learners found it difficult to understand the language of instruction of life sciences, partly because the learners are second-language speakers of English, and because they are not familiar with the concepts used in life sciences. Henry reported that his learners sometimes found it difficult to comprehend the investigative questions. The main reason for their failure to understand the questions, Henry said, was the language barrier, because his learners were second-language English speakers. He explained that his learners sometimes failed to understand the language:

I have had challenges with regard to how learners understand and interpret the investigative questions. This is because they are taught in English, a second language to them. So yeah, the language is a challenge.

Additionally, Henry also believed the learners' comprehension of the language used in life sciences was challenging. Though he did not give much detail on what he meant by the language used in life sciences, he stated that the subject has its own unique language, making it different from other subjects. His learners found it difficult to understand the concepts of life sciences and this reflected negatively on their participation in IBL and scientific investigations:

Within the school setting sometimes the language … The language of life sciences is a language on its own. Learners do not understand the life sciences concepts and they usually complain saying the subjects has many big words.

Similarly, Patience ascribed difficulties she experienced in implementing IBL successfully partly to the language of life sciences. Learners were unable to identify with the concepts that are used in life sciences, because these terms were not used in their everyday lives. Conducting scientific investigations was, therefore tremendously challenging, because the learners first needed to understand the language of the subject, before they could conduct the intended activities. She claimed that learners struggled to comprehend life sciences content, which also caused challenges regarding the implementation of IBL in Patience's classroom practice.

Experience has taught me that learners struggle to grasp the content of life sciences because of the terminology that is used in life sciences, which becomes a challenge because it is not their everyday language.

The two other participating teachers did not explicitly refer to language issues affecting their IBL practices. However, Linda implicitly suggested that, when she conducted scientific investigations, she had to explain language constructs, such as the meaning of the words used in the steps followed in conducting IBL, and the meaning of certain punctuation marks. This indicated that the language of instruction and the concepts used in life sciences were not always easy for learners to comprehend. She said,

> *I explain what an aim is; what a question mark is because they have to understand the meaning of the question mark.*

4.6.3 Professional development

Teacher professional development is crucial for the production of effective teachers, and to help them maintain the efficacy of their teaching. Angraeni *et al.* (2016) argue that IBL as a pedagogical method requires a great deal of professional teacher development to ensure teachers have sound knowledge to enact IBL successfully. Similarly, Tsakeni (2014) reflects on the significance of teacher professional development for the efficacy of IBL instruction. The subtheme focuses on activities that promote teacher professional development to equip life sciences teachers adequately to implement IBL. The subtheme is divided into the following categories: teacher training, content workshops, discussions with other teachers, teacher in-service practice, and roles played by subject advisors. The responses generated through semi-structured interviews generally refer to gaps in the relevance of current teacher development activities and their efficacy in preparing teachers sufficiently for IBL practices in life sciences classrooms.

4.6.3.1 Teacher training

The participants all received professional training as life sciences teachers at various institutions of higher education. However, the teachers were not confident that they had received sufficient preparation to ensure sound teaching of life sciences through IBL. Some of the participants stated that they had received training that prepared them for IBL practices, because they had done practical laboratory work during their teacher training. Linda, for instance, stated that, during her university training, she had been exposed to laboratory work. During these activities she had been involved in the hands-on dissection of organisms and other science laboratory work. However, it was not evident whether the kind of practical work she had done was IBL-inclined, since she had studied for a BSc qualification, which would hardly involve training on any teaching methodology in general, or IBL in particular. She doubtfully described the form of IBL training:

> *I think, I don't know exactly, but I think if I had just studied BA I wouldn't have been that exposed to life sciences I had with the BSc in physiology. So, I have been exposed a lot different types of things with dissections. I did it physically. I did all the practicals myself and that helps me a lot with my current practice.*

Amidst uncertainty about her professional development in IBL, Linda explicitly showed that she doubted whether she was sufficiently prepared to implement IBL. Responding to a question asking whether she regarded herself as being sufficiently prepared for IBL pedagogy, she said,

> *No. Not sufficiently. I am a bit but not sufficiently.*

Furthermore, she explicitly stated that, during her training to be a teacher, the focus had been primarily on subject content. It evidently lacked emphasis on teaching methodology, which arguably and implicitly suggests that there was no adequate, if any, form of IBL training to develop her professionally to apply IBL as a way of teaching life sciences,

> *In my training I was mostly taught the content but not much of how to teach it.*

However, Linda argued that she presented lessons that were entirely IBL-oriented during her teaching practice while studying for a PGCE. The argument revealed that she was eventually in a teacher qualification programme and her training in IBL was now evident. She described the PGCE training as having contributed to knowledge on how to teach through IBL:

Last year I was doing my PGCE they talked a lot about inquiry-based learning. And every lesson I had last year was inquiry-based and learner-based. It's been simulated but not practical yet.

Andy also attested to sufficient professional training as a teacher in general. She said the training was confined to imparting life sciences content to pre-service teachers. Other salient issues during her teacher training were time management and professionalism in general. She overtly referred to the absence of training on IBL pedagogy, by saying:

Remember I did a PGCE and even then, much of the training was on time management, the content and all the other things relating to professionalism but it was not directly based on teaching science through IBL.

Henry could not convincingly attest to receiving sufficient training to use IBL in teaching life sciences either. When he was asked if he considered himself to be adequately prepared to implement IBL, he said,

I cannot say I am adequately prepared but I am getting there.

He believed his professional training had prepared him to teach life sciences, and he was confident that he had learned the life sciences content well. On whether the training he had received to become a teacher who could implement IBL had been sufficient, he could not give a clear indication, but explained that he had been trained to teach life sciences in general:

Yes, I believe I was adequately prepared in terms of knowing and understanding the life sciences content, its practicality and how I should teach it.

The teacher training process Patience was exposed to also showed evidence of content teaching. She referred to a shortage of relevant training in teaching strategies, which, in particular, signifies that IBL was not part of her training. She emphatically stated that she had studied life sciences content, but she was left to figure out ways how she could teach it effectively herself. She succinctly described the nature of the training she had obtained regarding her teaching as follows:

> *Not really. Okay, you know sometimes they teach you the content of life sciences for you to be able to make somebody else, especially learners, to understand. One has to develop their strategies to teach.*

It is also noteworthy that she was not confident about whether she was sufficiently prepared to teach life sciences through IBL. She ascribed her ongoing training in this regard as relying on workshops, as she believed she would still receive professional training in using IBL. In her response, she explicitly spelled out that she was not yet ready to teach through IBL:

> *With the help of workshops and other assistance I will get better. Yeah, I will get there. I am not sufficiently prepared yet.*

4.6.3.2 Content workshops

This category refers to the workshops that are attended by life sciences teachers after they start work as teachers. It focuses only on workshops with a primary focus on enhancing teachers' knowledge of IBL in order to bolster their ways of teaching with IBL. The findings generated through semi-structured interviews reveal that teachers attended what they call content workshops, with little indication that IBL pedagogy was part of the issues discussed at the workshops.

Regarding Linda's professional development in relation to IBL, she does not believe workshops played a significant role. She stated that she had not attended many workshops:

> *Workshops, I haven't really attended a lot of them, I can't really speak much about those.*

Patience had attended several workshops since starting practicing as a life sciences teacher. However, she did not believe that the workshops played a role in her knowledge of IBL, nor her professional development for teaching life sciences. She believed workshops did assist her in her IBL practice, but only to some extent. She ascribed the workshop's lack of contribution to her IBL professional development to the fact that teachers who attended the workshops would have to implement the acquired knowledge at different schools with obviously different contextual factors.

> *Yeah, workshops do assist even though not completely because of different types of schools that we have. Something may work in another school and may not in another because of things happening in that school and what not.*

Patience emphasised the workshops' lack of effect on her professional development when she indicated that she was still not sufficiently prepared to implement IBL. She hoped she would become sufficiently prepared through future IBL-related workshops. Hoping that future workshops could assist professional development implicitly suggests that, at the time of data collection, she had not yet been exposed to workshops that could have a significant impact on her development. She stated that she was not well prepared, but was hopeful about future workshop activities, by saying,

> *With the help of workshops and other assistance I will get better. Yeah, I will get there. I am not sufficiently prepared yet.*

Andy shared similar perspectives. She was not entirely convinced that the workshops she had attended had prepared her entirely for IBL practices as a life sciences teacher. She reported that the workshops they had attended had tended to be more content based. The workshops reportedly did not focus on practices relating to teaching strategies in general or the implementation of IBL pedagogy in particular. She gave a brief account of the nature of workshops she had attended:

> *Okay most of our workshops are more content based, so they don't actually prepare you well in the workshops to be able to present the content and how to implement IBL.*

Furthermore, the participant argued that the workshops tended to offer too much information that she perceived as unnecessary. She found that the workshops consistently focused on generic issues that did not really assist her in her practice. It was not clear what she meant by unnecessary information, but may have implicitly suggested that the workshops did not prepare teachers for IBL practices. She stated,

> *Some of the contextual factors, they like to give a lot of unnecessary information. Even the content workshops tend to focus on that rather than focusing on the key aspects that we need to follow. Maybe if they can focus on key aspects rather than general things.*

Henry vaguely stated that workshops had some efficacy in helping teachers in their work, but he did not elaborate on how, specifically, they assisted teachers:

> *Workshops; they usually help a lot when you attend them. There's a lot of information you gain there.*

Responding to a probing a question on how, specifically, workshops had assisted him with to the implementation of IBL, he explicitly stated that he had not attended any workshop focusing on IBL practices:

> *I have not attended any IBL-specific workshop.*

4.6.3.3 Discussions with other teachers

Two of the four teachers stated that they had developed their IBL practices through interactions with other teachers at the school. By other teachers, the category refers to other life sciences teachers, senior teachers, including physical sciences teachers who engage in discussions with life sciences teachers. Linda described her relationships with her colleagues who also taught life sciences. Reflecting on the forms of assistance she received while teaching through IBL, she mentioned that she had consulted her colleagues, who apparently assisted her to make her IBL practice a success. It is noteworthy that no sound explanation was given as to how, precisely, the other teachers assisted her to ensure that the way she teaches is IBL improved. She gave a brief description of the relationships she had with her colleagues and attempted to indicate that her IBL practices were enhanced and developed through such interactions:

> *My colleagues help me ensuring that I teach the correct thing. If I struggle with something while conducting the investigation, I get support from the other life sciences teachers.*

In a controversial comment, Linda also reflected on how other teachers influenced her choice to employ IBL in her teaching negatively. She argued that not all teachers who had been teaching longer than she had advocated IBL pedagogy, and some were not willing to support anyone who intended to use IBL. She stated that such teachers assertively discouraged others from using IBL, by claiming that it was not an ideal pedagogical approach to life sciences teaching. She stated,

> *All the teachers who have been teaching before me aren't keen on trying new things. That's the reason why we are not sufficiently prepared, because the older teachers will just discourage you, 'it's chaos, just don't do it'.*

Andy also reflected on the effect of other teachers, particularly at the school she worked at, on her IBL practices. She mentioned that the head of department of life sciences ensured that activities were of a high quality, provided assistance regarding IBL activities and ensured that the teachers had all the equipment and materials they needed for scientific investigations using IBL. She gave a brief description of how the department had assisted her to do advocacy for IBL pedagogy:

> *We have a departmental group here in our school. If we have to do any work it goes through the HOD [head of department], she checks up the work, she makes sure it's up to standard. She assists with regard to intended activities, especially those that need your IBL expertise. If you have something to buy to use in teaching, you do so through the department.*

4.6.3.4 Roles played by subject advisors

Henry reported on intervention programmes by subject advisors that were meant to improve teachers' IBL practices. However, it was questionable whether the interventions were really IBL inclined, because he did not dwell much on his explanation of how the interventions trained teachers for IBL implementation. He stated that that the subject advisor visited the school to give guidance on IBL practices. In answer to the question asking what form of assistance he had received on the implementation of IBL, he mentioned that the subject advisor visited the school for guidance and offered assistance to teachers during workshops. However, Henry only referred to the workshops generally, as focusing on scientific investigations, and did not provide enough evidence that they were on IBL:

> *Yeah. The subject specialist does come to visit our school to offer some guidance. Even at the beginning of this year we were helped on how to do them. The workshop was about conducting scientific investigations. The subject advisor explained key concepts in scientific investigations, but it was a very short session.*

Patience shared similar information about subject advisors' roles in her IBL-related professional development. She confirmed that the subject advisor played some role in her IBL-related professional development. Her explanation was, however, ambiguous because she only said the subject advisor explained in a workshop how teachers should carry out scientific investigations. It is, therefore, not evident whether the workshops were IBL inclined, because scientific investigations can still be conducted outside the parameters of IBL. Responding to a question asking whether she had received any form of assistance with her IBL practice, she said,

> *Yes. There is support from the subject advisor who conducts some workshops wherein he explains to teachers how they should conduct scientific investigations.*

Andy, on the other hand, mentioned that she needed assistance from the subject advisor, because she doubted the knowledge she had at the time of data collection regarding IBL practices and pedagogy was sufficient. However, she stated that she had not received much of any form of IBL-related assistance from the supervisor. Admitting she would welcome some of assistance from the supervisor, she said,

> *Sometimes we feel like the knowledge we have is not enough and it would be good to get some assistance from the subject advisors.*

4.7. SUMMARY OF THE CHAPTER

This chapter presented the findings of the study and provided a presentation of qualitative methodology case study research. The purpose of the study was to explore how life sciences teachers implement inquiry-based instruction. The design allowed for in-depth analysis, and resulted in findings on the three guiding secondary research questions. The results suggest that teachers have different perceptions of inquiry-based instruction. Furthermore, the results reveal that life sciences teachers use different forms of structured inquiry, and that their practices are influenced by a variety of contextual factors, such as school setting, professional development and various policies.

Chapter 5 will discuss the findings in greater depth, by linking it to some of the literature that had been presented in Chapter 2. The next chapter will also explore the implications of the findings, make recommendations and provide suggestions for further research.

CHAPTER 5:
DISCUSSION OF FINDINGS AND CONCLUSIONS

5.1. INTRODUCTION

The final chapter will present a discussion of findings and conclusions. The chapter will start with a summary of how the study was conducted. Following this summary, I will discuss the significance and implications of the findings, and conclude with recommendations for further research. The last part of the chapter will outline the conclusions of the study. Furthermore, it is significant to outline a discussion on the methodological approach used for this qualitative study that explored the practice of IBL by life sciences teachers, particularly for life sciences teaching in Standerton.

In the South African context, inquiry learning in life sciences has not received much attention, since most research in the area of IBL pedagogy in the country has focused largely on physical sciences. It is, therefore, imperative to capture this methodological contribution of the study in order to enable other researchers to extend the methodologies required for studies of this nature. The interpretation and discussion of the findings are related to the literature review that was presented in Chapter 2. Research methodology relating to the way data were collected and analysed relates to the discussion on methods and processes discussed in Chapter 3. Finally, recommendations for future studies, conclusions of the study, and a synthesising statement that is aimed at capturing the main thesis of the present study will be outlined.

5.2. SUMMARY OF THE RESEARCH

The present study explored how life sciences teachers incorporated IBL in their teaching, by determining their perceptions and exploring their ways of implementing IBL pedagogy. The contextual factors surrounding and influencing the teaching of life sciences through inquiry-based pedagogical approaches were also explored. Findings revealed that the participant teachers had different perceptions and views on IBL, which implicitly guided and shaped their practices in their classrooms. Furthermore, the study showed that IBL practices in life sciences classrooms of the four participant teachers were significantly influenced by a repertoire of contextual factors, which were evidently experienced differently by teachers at different schools.

The study was encouraged by research evidence that IBL has increasingly become a way of teaching that is effective for teaching science subjects. Timmerman *et al.* (2016) reflect on "a pragmatic investigation into the efficacy of inquiry-based curricular reforms compared to traditional laboratory activities that was undertaken in the introductory life sciences course for majors at a large state university in south eastern United States". The study corroborates other studies that were undertaken in the field of inquiry-based science education by reporting that learners showed a great deal of improvement in their academic achievement in life sciences (Waters, 2012; Hughes & Ellefson, 2013; O'Sullivan, 2012). However, the authors distinguish between concrete topics, such as anatomy, and abstract topics, such as evolution, and argue that inquiry-based sciences education proved effective and yielded positive results in the abstract topics (Timmerman *et al.*, 2016).

Research in the African context in general, and the South African context in particular, however, indicates that even though life sciences teachers are embracing the use of IBL pedagogy, there are still gaps regarding the efficacy of practical implementation (Leon, 2012).

Inquiry-based science teaching has been adopted by African states, such as Rwanda (Leon, 2012). Leon (2012) argues that, even though some of the life sciences teachers in Rwanda have shown an appreciation for IBL to teach life sciences, most teachers still find it difficult to practice the approach. Like in most other African states, contextual factors, such as lack of resources, overcrowded classrooms and teachers' lack of confidence still hinder the implementation of inquiry-based science teaching (Leon, 2012).

Despite evidence of the effectiveness and applicability of inquiry-based teaching in life sciences, South Africa is still at a stage where life sciences teachers are unsure about and are not adequately trained in the implementation of inquiry-based science education (Ramnarian & Hlatshwayo, 2018). Mogofe and Kibirige (2014) posit that teachers who are qualified to teach life sciences are uncertain about the conduct of inquiry-based practical work, which is reflected in poor learner performance in life sciences. Furthermore, they argue that teacher training in this regard cannot be confirmed, as the teachers are unable to translate their training into practice (Mogofe & Kibirige, 2014).

The present study was guided by interpretivism as research paradigm and the lens through which data were collected, and followed case study as the research design. Due to the nature of data that were required to answer the research question, the study employed a qualitative approach to explore the issues of interest, and used semi-structured interviews as the main data collection method, and non-participant observation of life sciences lessons for triangulation purposes. Furthermore, social constructivism emphasises that learners construct new understandings using their current knowledge, and that learning is not passive, but involves learners who ask questions actively. Learners have to find answers themselves, and doing so culminates in the development of meaningful knowledge (Amineh & Asl, 2015). A guided inquiry conceptual framework helped me interpret and understand the teachers' practices in teaching life sciences using IBL.

Qualitative research was employed because it was appropriate for the nature of the study, which did not collect numerical data. Furthermore, this approach to research was relevant to the study because the meaning of the activities of the teachers in their practice of IBL was investigated. The participants and the phenomenon – the practice of IBL in the teaching of life sciences – were studied within their natural contexts, the classroom and laboratory, and I was primarily engaged with the participants to make sense and gain an understanding of their actions within their contexts, which confirms the suitability of the case study research design (Gaya & Smith, 2016).

The qualitative research method allows participants to speak in their own voices, rather than conforming to the categories and terms imposed on them by others. The nature of the research approach enabled me to investigate and explore the practice of IBL in teaching life sciences in classrooms where actual teaching takes place. People or phenomena are studied in their natural settings, and researchers believe that action can be understood when it is observed in the setting within which it occurs naturally (Kohn & Christiaens, 2012).

Overall, the study sought to answer the primary research question:

How is IBL practised in life sciences classrooms?

In addition to the primary research question, the study sought to answer three secondary research questions, which all generated elaborate responses that could answer the main research question. The secondary research questions and the relevant data collection methods and instruments are summarised in Table 5.1.

Table 5.1: Secondary research questions and instruments

<table>
<tr><th>Research question</th><th>Research Instrument</th></tr>
<tr><td>1. How do life sciences teachers perceive the use of IBL in life sciences classrooms?</td><td>Semi-structured interviews</td></tr>
<tr><td rowspan="2">2. What strands of inquiry are currently practiced in the teaching of life sciences?</td><td>Semi-structured interviews</td></tr>
<tr><td>Lesson observation</td></tr>
<tr><td>3. How do contextual factors influence the practice of IBL in the teaching of life sciences?</td><td>Semi-structured interviews</td></tr>
</table>

Table 5.1 shows each of the three secondary research questions with the research instruments that were used to unpack the study. The study used a qualitative approach, with semi-structured interviews used as the main data collection method. To triangulate the findings, data collection was also done through non-participant observations, which focused on the teaching practices of the participant teachers. Secondary research questions 1 and 3 were answered by the data generated by the semi-structured

interviews. Research question 2 was answered by the data collected from lesson observations, during which field notes were taken and an observation protocol was used as an instrument to stipulate key observations that were envisaged to be sufficient to answer the research questions. In the final analysis, all the answers responded to the main research question, which asked how life sciences teachers practise IBL in the classroom.

The following section expounds on the findings of the study, and explores their theoretical significance and implications for policy and practice.

The theoretical framework chosen for this study was social constructivism. Social constructivism provided a detailed interpretation and explanation of the data that was collected. In their practice of IBL, life sciences teachers help learners to construct their own knowledge by applying the basic tenets of social constructivism, which do not deviate from the significance of collaborative activities to construct knowledge. Guided inquiry, as a form of scaffolded inquiry, described by Kuhlthau *et al.* (2007), was used as a conceptual framework, as it corroborates the basic tenets of social constructivism. However, in this study, the concept scaffolded inquiry was used, so that the rubric showing the levels of inquiry, including confirmatory inquiry, structured inquiry and guided inquiry, could be used to determine the levels of inquiry practiced by the teachers. Scaffolded inquiry is a form of inquiry in which learners work together with a common goal to create knowledge, in the presence of a teacher who acts as a facilitator and who offers intervention throughout the process of inquiry, to elicit deep learning and personal understanding (Kuhlthau *et al.,* 2007).

This study expected four teachers from three different schools to reflect on their own practices of IBL in teaching life sciences. Most significantly, the study explored the semi-structured interview and non-participant observation results, and compared them to come up with a comprehensive, triangulated explanation of the practices of IBL that were incorporated in the work of the participant teachers. In discussing the key findings of this study, I also sought to examine their significance by responding to the main research question about the way life sciences teachers practice IBL. It was of paramount importance to establish an understanding on how to implement IBL successfully, to ensure that teachers who are adept at teaching through inquiry activities are prepared, largely because the IBL teaching approach has recently gained traction and has been found to be effective for teaching science subjects in general and life sciences in particular.

5.3. KEY FINDINGS AND THEIR SIGNIFICANCE

Inquiry-based instruction has been adopted by many countries for their various curricula across the world. Life sciences is not an exception, as scientists advocate for a revolution in the pedagogy of life sciences; they claim such a revolution is inclined to the use of inquiry-based science education as an approach to the teaching of the science subjects, which includes life sciences (Wood, 2009; Almroth 2015). In spite of the growing popularity of IBL for life sciences teaching, within the South African context, it remains a challenge to ensure its sound implementation.

Various contextual factors threaten the successful, effective implementation of IBL according to the CAPS in South African high schools. These contextual factors include teacher professional development, which, according to literature, remains uncertain in the South African context (Mogofe & Kibirige, 2014). The study, thus, sought to explore how life sciences teachers implemented IBL, by investigating mainly their perceptions regarding IBL, the forms of inquiry they employed in their teaching, and how contextual factors reflected on and influenced their classroom practices. It is hoped that an understanding of life sciences teachers' IBL practices will contribute to developing teachers who are adept at implementing inquiry-based life sciences instruction, and doing so effectively.

The major findings of this study will be addressed in sections that align with the themes that were developed during data analysis. These themes are teacher perceptions, strands of IBL, and contextual factors.

5.3.1 Teacher perceptions

5.3.1.1 Creative thinking

Internationally, literature indicates that learning is not passive, but involves learners who ask questions actively, think creatively and find answers on their own, which culminates in the development of meaningful knowledge (Amineh & Asl, 2015; Kim, 2006; Walker, 2007). Research findings in the South African context reveal that "learners actively develop their understanding of science by combining scientific knowledge with reasoning and creative thinking when engaging in inquiry" (Ramnarian & Hlatshayo, 2018). Furthermore, IBL has been found to be an effective teaching method for science subjects, as it promotes creative thinking in knowledge construction (Kazeni *et al.*, 2018).

For this study, IBL in life sciences teaching was found to be instrumental in developing learners' creative thinking skills. Henry, Patience and Linda advocated for teaching life sciences by following inquiry-based approaches. With IBL, learners do not only think within the confines of pre-existing knowledge as outlined by textbooks; instead, they are afforded opportunities to think scientifically and creatively to construct their own valuable knowledge. Linda's perception of IBL suggests that she construed it as being effective for developing critical, creatively thinking learners – similar to scientists who use the scientific method in generating knowledge. When learners work in groups on a practical activity or any scientific investigation activity, they are given an opportunity to think creatively and follow the steps scientists follow when they use the scientific method.

Henry's view of IBL as significant in stimulating creative thinking was similar. Learners worked together in an investigation, following the teacher's procedure. However, the learners were allowed to be innovative in designing their own, alternative procedures to find the solution and answers to the question. Henry explained that learners help each other in the small groups they work in when they try to explain the procedure to each other. The acts of reworking the procedure and helping each other throughout the practical activity stimulate creative thinking, thereby preparing learners for and affording them opportunities to apply the scientific method.

Patience also held strong views and perceptions about inquiry lessons being characterised by ongoing processes of creative thinking. Her perception was that, to administer inquiry-based pedagogy, learners should be grouped so that they could mutually interact while working towards a common goal. Among other benefits, learners shared their ideas about the hypotheses they proposed for a given practical investigation. In the process, they thought critically to come up with ideas and tried to work towards formulating hypotheses that would be followed by the group. She regarded IBL as being instrumental for enabling learners to think creatively; discussing it with the whole group while they worked towards coming up with conclusions also played a role in stimulating creative thinking.

In a nutshell, in this study, IBL for teaching life sciences was perceived by the participant teachers as being relevant for producing learners who could think creatively. When working on scientific investigations, learners worked together to construct knowledge just as scientists do. These groups afforded learners opportunities to work together in an attempt to contribute to the construction of knowledge. Their interactions in groups elicited application of creative thinking skills, which the participants regarded as significant for applying the scientific method.

5.3.1.2 Interactive learning

Internationally, literature indicates that science teachers who practise IBL hail it for promoting learner collaboration and interaction in the science classroom, and for constructing meaningful learning (Amineh & Asl, 2015; Kim, 2006). Similarly, South African literature attests to IBL being characterised by interactive learning, because it creates opportunities for learners to work together in constructing knowledge in the science class (Ramnarian & Hlatshwayo, 2018). The literature corroborates the findings of this study, as the four participant teachers perceived IBL as being effective in creating interactive learning among learners. They were all able to promote interactive learning, because they all used groupwork when administering IBL-inclined lessons. Grouping the learners was the element that ensured an ongoing process of interactive learning.

The participant teachers hailed IBL for affording learners opportunities for interactive learning, during which learners tended to learn best because they understood the work better when it was explained at their own level, and the teacher's role was limited to instructions. The participants believed that learners learn better from their peers than from their teachers. This coincides with the proposition by Ramnarian and Hlatshwayo (2018), who propound that constructivist pedagogical approaches promote effective learning through learner interaction.

IBL was perceived by the participant teachers in this study to be a way of unleashing and maximising learning through learner interactions during the groupwork they carried out during inquiry scientific investigations. In addition to the academic benefits accruing from inquiry-based pedagogical activities, learners developed sound interpersonal skills as they interacted with their peers in their groups, thereby developing beneficial skills – they would become effective in using the scientific method to construct knowledge, and these skills would be useful to them in the workplace in the future.

5.3.1.3 Learner active involvement

Two of the four participant teachers perceived IBL as being instrumental in ensuring that learners take an active part in their learning. Their views corroborate the discussion by Haury (1993), who describes inquiry-oriented science instruction as being characterised by active learner involvement, hands-on activities and a discovery approach, which underlies the scientific method. The participants upheld the ideology that learning life sciences does not take place in a situation in which the teacher employs traditional pedagogical methods that are characterised by the teacher taking a more active, predominant role. In the latter case, the teacher is regarded as the only person who can impart knowledge to the learners. When she was asked to explain why she valued IBL in her teaching practice, Patience stated that IBL lessons are characterised by active involvement by learners.

Henry had a similar way of thinking, and argued that, since his IBL practices mostly took the form of practical work, learners understand better when they do practical work. He explained further that IBL has a way of eliciting maximum learning, because IBL activities ensure that learners are actively involved in lessons. Like Patience, he compared lessons in which learners are actively involved with lessons characterised by traditional pedagogical methods, which are dominated by teachers, and he asserted that learners learn effectively when they are actively involved in lessons.

In this study, the participant teachers held strong views and perceptions about IBL pedagogy and interactive learning. They affirmed that learners learnt best when they were afforded opportunities to work collaboratively, and interacted with each other in the groups they had formed during scientific investigation activities. They subsequently hailed this way of learning as being an effective way of learning life sciences.

5.3.1.4 Inquiry-based learning generates learner interest in life sciences

Internationally, research indicates that IBL is instrumental in improving learner motivation and eagerness, and encouraging them to show a high level of confidence in learning science subjects; which, in turn, encourage them to learn and develop sound thinking and processing skills (Badti *et al.*, 2018; Bevins & Price, 2016; Walker, 2007). In the South African context, scholars argue that doing inquiry while teaching science subjects instils motivation and stimulates learners' interest (Ramnarian & Hlatshwayo, 2018). The findings of this study support these findings of literature because, in the present study, two of the four participant life sciences teachers perceived IBL as being instrumental in generating learner interest in the subject, which is essential, since it is not feasible to teach learners a subject they are not interested in. Patience explained that, by engaging learners in scientific investigation activities that were inquiry-inclined, learners were afforded opportunities to realise the links between life sciences and everyday life experiences. Such understandings created a foundation for the learners to develop an interest in learning life sciences.

Andy held similar views regarding the perceived benefits of IBL to her practice as a life sciences teacher. One of the advantages of IBL in her teaching was that it provided learners with visual stimulation. She explained that learners constructed knowledge effectively and understood content through visual stimulation. Visual stimulation, subsequently, generated learners' interest in learning life sciences.

The study revealed that learners developed interest in life sciences when they were taught through inquiry-inclined pedagogy. Factors such as visual stimulation and IBL's ability to elicit a link between classroom activities and everyday life experiences of learners contributed to ensuring that learners develop an interest in life sciences. As a result, the teachers perceived IBL as a way of developing learners' interest in learning life sciences.

5.3.2 Strands of inquiry-based learning

As I stated in Section 2.5.3, the conceptual framework of this study was guided inquiry, though I chose to use the concept scaffolded inquiry, so that I could use the rubric showing the levels of inquiry, accommodate other forms of inquiry, excluding open inquiry, and avoid confusion about the meaning of guided inquiry. Structured inquiry is one of the three forms of inquiry (confirmatory inquiry, structured inquiry and guided inquiry) that are characterised by the presence of the teacher to give assistance to learners during scientific investigation activities. The four participants who were interviewed and whose lesson presentations were observed practiced structured inquiry. Guided inquiry practices of each of the three participants will be discussed in the section below.

5.3.2.1 Structured inquiry

Internationally, literature describes structured inquiry as the type or level of inquiry in which the teacher poses the question to be investigated and the procedure to be followed to answer the question, to the learners, but they are not given the outcome (Whitworth *et al.,* 2015; Smetana & Binns, 2005; Zion & Mendelovici, 2012).

Furthermore, learners engage in scientific procedures, which stimulates the development of basic scientific inquiry skills, such as making observations, formulating hypotheses, collecting and organising data, drawing conclusions, making inferences and finding solutions (Zion & Mendelovici, 2012). The teacher is present during the lesson, and offers support and guidance to the learners (Smetana & Binns, 2005).

The findings of this study reveal that the participant teachers practiced structured inquiry in different ways, which supported the descriptions in the literature. This finding was also made by Tsakeni *et al.* (2019) in the context physical sciences teaching in South Africa. The teachers all gave the investigative question to the learners, prescribed the methods the learners had to use to carry out the investigations, and supported learners to draw their own conclusions after their observations. Linda assumed a supportive role during scientific investigation activities, and learners, in groups, engaged in hands-on activities by following the steps of inquiry practically. She stated the aim of the anticipated scientific investigation to the learners, who then worked to formulate the aim of the investigation. Learners were given the method they had to follow in conducting the investigations. She allowed learners to work together during the investigations and only availed herself when learners needed her support. Once they had reached their conclusions, the groups communicated their findings with other groups by engaging in class discussions.

Similarly, Andy described a form of IBL that resonates with structured inquiry. Her emphasis was on letting learners work independently in her presence. She provided the necessary guidance when the learners had questions. She stated that learners were responsible for formulating their own hypotheses – her role was to explain to them the meaning of hypothesis. She emphasised the issue of autonomous learning, after which learners communicated their group findings in the form of class discussions.

She explicitly stated that she guided learners through the procedure or the method they had to follow during the investigation, and they were only allowed to work according to the procedure she had designed for them. Then, learners followed the step of formulating an investigative question, which is one of the crucial steps to get the inquiry process started. She indicated that they normally worked with sets of several questions that had to be answered. Learners were guided towards choosing the most encompassing question, as the one that would be used as an investigative question. It was the learners' responsibility to formulate the question, guided by the teacher. Following the selection of the investigative question, learners made observations and used the observations to reach conclusions. She encouraged learners to engage in class discussions, as a way to report their findings to other learners in other groups.

Henry grouped learners for scientific investigation activities. Learners were given the procedure that they had to use for conducting the scientific investigation. Henry was present while the learners worked on the investigation, and he offered guidance. He said he explained to them how to follow the steps of the investigation, which prevented them from working towards irrelevant results, and spending too much time on one activity. He also practiced structured inquiry, because he assisted learners to formulate investigative questions and he explicitly gave them the methods they had to use to conduct investigations. While they followed the teacher-determined procedures, learners were monitored and assisted by the teacher to conduct the investigations and make observations. Learners were then encouraged to communicate their findings through classroom discussions.

Patience's IBL practices were also in line with structured inquiry, because learners were given the research questions and methods to conduct the investigation. She reported that she worked with the learners from the onset, by assisting them to formulate the investigative question, which implies that she applied some form of scaffolding in the lesson. She did not give learners the autonomy to decide on their own what investigative questions to set. Instead, she provided the questions. Following their observations, learners drew conclusions and communicated their findings through class discussions.

The findings of this study reveal that the four teachers practiced structured inquiry. The rubric that shows how inquiry practices move along the continuum, from confirmatory inquiry to open inquiry, indicates that structured inquiry is characterised by the presence of the teacher during the inquiry-inclined lesson. The participant teachers' IBL practices supported this. Teachers indicated during semi-structured interviews, and it was evident during lesson observations, that they provided scaffolding when they practised IBL-based scientific investigations.

5.3.3 Contextual factors

Internationally, there are contextual factors that preclude the successful and effective implementation of IBL. In Chapter 4, the contextual settings of the schools in which the four participating teachers practiced their life sciences teaching were described briefly. The contextual settings at these schools varied a great deal, and this influenced the teachers' IBL practices. In the present study, contextual factors were divided into school setting, policies, and professional development. Each of the three factors is discussed in this chapter (see Sections 5.3.3.1 to 5.3.3.3). Various contextual factors that relate to school settings and professional development may have influenced the implementation of IBL in the participants' life sciences classrooms.

5.3.3.1 School setting

Under school settings, my focus was on school infrastructure, time constraints, class sizes, types of learners and extracurricular activities, because they emerged as the main, overarching categories during data analysis.

a) School infrastructure

School infrastructure refers to the availability and the state of laboratories and classrooms in which inquiry-based life sciences lessons were conducted. Internationally, it is well-documented that some schools lack appropriate teaching materials, such as science laboratories, which negatively affects teachers' confidence for using inquiry-based pedagogical approaches to teach science (Kang & Keinonen, 2016). The findings of a study conducted in Uganda by Ssempala (2017) reveal that the implementation of IBL in developing African countries is challenged by a lack of infrastructure, such as laboratories. South African scholars have also reported that implementing IBL for teaching science subjects, including life sciences, has been derailed by a lack of laboratories at schools, especially those that were previously disadvantaged, mainly as a result of political issues (Tsakeni, 2018; Ramnarian & Hlatshwayo, 2018; Gudyanga & Jita, 2019).

The findings of this study do not entirely support the literature in this regard. Three of the participants (Linda, Andy and Henry) asserted that their schools had laboratories; hence, some of their inquiry activities took place in laboratories in the form of practical work. Linda and Andy were at the same former Model C school, which had two laboratories. Henry also had access to and could teach in the only science laboratory of his rural school. However, Henry did not actually have all the benefits of having a laboratory at his school, because of other factors, such lack of laboratory equipment. As a result, he had to conduct most of his IBL activities in a classroom. Furthermore, this study's findings reveal that one of the participant teachers, Patience, worked at a school that had no laboratory. Therefore, Patience implemented IBL activities in an ordinary classroom that had no science material whatsoever. This affected her IBL practices negatively, as learners had no exposure to real scientific contexts and could not experience the feeling of simulating scientists while they worked.

The findings of this study with regard to the availability of laboratories reveal that this factor influenced the participant teachers' IBL practices in different ways. Two of the four participant teachers relished working in a context that allowed them to practice their IBL practical work, because they had access to laboratories. They also taught in well-resourced classrooms, which arguably had a positive impact on their choice to use IBL pedagogy. In turn, one teacher had access to a laboratory, though it was not as well equipped as he required; hence, its availability did not assist him to realise his full potential in practising IBL. The other teacher did not have a laboratory at her school, which forced her to practise IBL in an ordinary classroom.

b) Laboratory equipment

Literature in the South African context reveals that IBL implementation is expected to be implemented in schools that have shortages of or no laboratory facilities, equipment and materials (Tsakeni, 2018; Motlhatlhedi, 2015). Arguably, these factors affect the implementation and efficacy of inquiry-based practical work. Furthermore, learners in under-resourced schools often lack access to laboratory facilities and the relevant apparatus to perform hands-on scientific investigations (Tsakeni, 2018). The findings of this study support the literature. All four participating teachers' IBL practices were influenced by the availability of laboratory equipment and apparatus. Two participating teachers were from schools whose contexts were characterised by a shortage of relevant laboratory equipment, including the pertinent apparatus required to administer practical work-based IBL instruction in life sciences – these teachers were Patience, at a township school, and Henry, at a rural school. They both worked in contexts characterised by a shortage, or, sometimes, an absence of relevant apparatus for conducting scientific investigations as a way of practising IBL. These shortages were reflected in the frequency of their IBL practices, as such activities were limited in their classes. Patience sometimes lacked appropriate equipment and apparatus to conduct IBL activities. Even when the school had the relevant equipment, it was often not enough. Both the conditions – insufficient equipment, and no laboratory equipment at all – negatively reflected on her IBL practice. She sometimes had to improvise by resorting to teacher demonstrations, instead of exposing learners to real, hands-on scientific investigations. In extreme situations, she ended up merely explaining the activities to the learners. Having teacher demonstrations and explaining scientific investigations do not reflect the basic tenets of scientific inquiry. Henry stated that the laboratory he had access to did not always have a supply of the required equipment or apparatus. He was sometimes required to improvise, thereby compromising the authenticity of IBL practices, to comply with the requirements of the curriculum.

The other two participant teachers explicitly argued that they worked at a school that was rich in terms of the availability and adequacy of laboratory material. However, even though they enjoyed the benefits of working in a sufficiently resourced school, one of them also reported being confronted with situations for which she did not have the relevant laboratory equipment. Andy pointed out that the CAPS, the South African curriculum, sometimes prescribed scientific investigations the school had no equipment and materials for. Therefore, sometimes, she was unable to carry out either her desired investigations, or those prescribed by the CAPS – which had a negative impact on her IBL practice. In a nutshell, the findings reveal that the four participant teachers experienced challenges regarding the availability of laboratory material and relevant apparatus. However, the degree to which the challenges were experienced by the teachers varied. Two teachers who taught at a former Model C school were not particularly challenged, while the other two teachers reported having limited access to the required material and relevant apparatus.

c) Time constraints

In the international context, literature reveals that life sciences teachers face challenges related to allocating time for teaching while implementing IBL pedagogy (Barrow, 2006; Van-Diepen Scheerboom, 2017). South African teachers of science are no exception, as scholars explain that teachers have to implement IBL in the face of too little time available (Ramnarian, 2016; Motlhatlhedi, 2015). Furthermore, “time constraints are a complex phenomenon. Inadequate practical skills, large administration workloads, large content or complex content, may all lead to challenges that can manifest as time constraints” (Gudyanga & Jita, 2019). The findings of this study also reveal that three of the four teachers experienced time constraints in different ways, which had a negative impact on their IBL practices.

Linda found time a challenging factor that did not allow her to carry out IBL activities. She indicated that, sometimes, the main concern was covering the large amount of life sciences content in the curriculum. Consequently, she found it difficult to complete the content within the time available, and it was sometimes difficult to fit in scientific investigations, as they require more time. It was challenging to conduct inquiry activities with so much of the focus on teaching all the topics prescribed by the CAPS. Andy also reported not being able to conduct as many inquiry activities as she would have liked, or sometimes even those prescribed by the CAPS. The number of scientific investigations that could be executed was sometimes influenced by time constraints.

Henry also referred to the time factor as one of the challenges facing his practice of IBL. He stated that he could not conduct all the prescribed scientific investigations. The life sciences FET curriculum was congested with content and teachers were required to focus on completing it. As a result, Henry found it challenging to cover the content with the learners while also incorporating IBL-based scientific investigations in his practice.

The findings of this study reveal that teachers in this study found it challenging to allocate time for IBL practices. Other factors, such as the congested life sciences curriculum, threatened their autonomy to use IBL pedagogy optimally. Time constraints, therefore, impacted the IBL practices of the participant teachers negatively.

d) Class size

Internationally, literature reveals that class sizes have an impact on IBL practices in life sciences classrooms. Ssempala (2017) propounds that, in developing African states, IBL in life sciences teaching takes place in overcrowded classrooms. According to Marais (2016), overcrowded classrooms remain a challenge in South African schools, and the problem remains largely unaddressed. South African schools are characterised by a high learner to teacher ratio, which makes it difficult for teachers to implement certain strategies, including IBL, when teaching science subjects (Dudu, 2014a; Samuels & Dudu, 2017).

The propositions in the literature support the findings of this study, because one of the four participants reported overcrowding in her life sciences classroom. Patience affirmed that she taught large classes in a township public school. She indicated that numbers in her classes were abnormally high and, as a result, it was difficult to administer IBL-inclined lessons, as she even did not even have sufficient space to move around.

5.3.3.2 Professional development

An overarching challenge internationally is that life sciences teachers lack professional development in IBL instruction (Barrow, 2006; Lederman *et al.*, 2013; Papaevripidou *et al.,* 2018; Angraeni *et al., 2016*). In many science subjects, including life sciences, teachers still do not practice inquiry-based learning due to factors such as teachers' lack of knowledge of IBL and their preference for direct and teacher-centred approaches – tendencies that are attributed to shortcomings in IBL-related professional development (Barrow, 2006).

In the South African context, literature points out that there is an unresolved shortcoming regarding professional development that is intended to prepare life sciences teachers for effective implementation of IBL in their teaching (Dudu, 2015; Ramnarian & Hlatshwayo, 2018). Dudu (2015) posits that teacher development intervention activities in South Africa do not address the needs of the educators, and seldom improve the practice of teaching science subjects. This study generated similar results. Teachers who participated attested to several forms of teacher development activities that were meant to contribute to their IBL professional development; however, the teachers pointed out that they were not sufficiently prepared for IBL-inclined pedagogy, which suggest that the teacher training activities were not effective.

a) Teacher training

Internationally, literature indicates that where teacher training is ambiguous regarding the types of activities and content to be learnt through inquiry, inquiry-based pedagogy has limited effectiveness (Bevins & Price, 2016). According to Papaevripidou *et al.* (2018), most science teachers prefer to use traditional teaching methods over IBL because they did not receive sufficient training in inquiry-based pedagogy. Angraeni *et al.* (2016) argue that some teachers have not been exposed to the teaching of life science through inquiry, neither during their schooling days, nor during their college training. Locally, literature indicates that science teachers tend to teach the way they were taught, which limits their practice of IBL because they were not sufficiently trained to implement IBL (Ramnarian & Hlatshwayo, 2018; Dudu, 2014a).

The findings of the study corroborate the literature, because the participant teachers did not confidently attest to the contributions of their university training in preparing them to implement IBL. The participants had all received professional training as life sciences teachers at various institutions of higher education. However, the teachers were not confident that they had been prepared sufficiently to ensure sound teaching of life sciences using IBL. The teacher training programmes they had been exposed to effectively only taught them the content of life sciences – IBL-related teacher professional development was lacking. Some of the participants stated that they had received training that prepared them for IBL practices, because they had conducted practical laboratory work during their teacher training.

The situation for Andy's practice was similar. She reported sufficient professional training as a teacher in general, with no evidence of training in IBL-oriented pedagogy. She said all the training was confined to imparting life sciences content for pre-service teachers. Henry also failed to convincingly attest to having received sufficient training to use IBL for teaching life sciences. He was only confident about his knowledge of the life sciences content he had acquired during his years of teacher training; however, he said less about being trained for the implementation of IBL. Patience also reported a lack of explicit training in teaching methodology in general, and IBL pedagogy in particular.

The findings of the study reveal that the participant teachers had not been sufficiently trained to implement IBL. There was no evidence that their years of teacher training had equipped them with the necessary knowledge and skills to implement IBL pedagogy. Their responses during semi-structured interviews revealed that, during their teacher training years, the focus had been primarily on teaching them the life sciences content, rather than IBL pedagogy.

b) Content workshops

Internationally literature reveals that teacher development activities focused on preparing teachers to implement IBL are not always effective (Lederman *et al.,* 2013). Similarly, literature states that IBL-oriented teacher development activities such as workshops are not effective in preparing teachers to implement IBL (Dudu, 2015; Ramnarian & Hlatshwayo, 2018). This study generated findings supporting the findings in the literature. The findings of this study reveal that the participant teachers were exposed to some life sciences content workshops. The workshops, however, did not elicit the desired outcomes in terms of preparing the teachers for IBL practices. Three teachers asserted that the workshops were not effective in contributing to their knowledge of IBL pedagogy. Patience had attended several workshops since starting work as a life sciences teacher. However, she did not report the workshops as having played a role in her knowledge of IBL, nor her professional development for teaching life sciences through IBL. She made reference to the workshops' lack of efficacy for her professional development when she indicated that she was not yet sufficiently prepared to implement IBL, and the workshops had not had the desired impact.

Andy was, similarly, not entirely convinced that the workshops she had attended had prepared her for IBL practice as a life sciences teacher. The workshops were more content-based and did not focus on teaching strategies in general or IBL pedagogy in particular. Henry was explicit in stating that the workshops he had attended did not focus on IBL pedagogy. The findings reveal that the teachers only had opportunities to attend content workshops and there was little, if any, focus on IBL pedagogy. Therefore, the workshops did not play an evident role in preparing the participant teachers to implement IBL.

c) Subject advisors

Internationally, literature indicates that there is insufficient professional support for teachers to improve their IBL practices (Barrow, 2006; Bevins & Price, 2016). Such a lack of support has resulted to some teachers confining their IBL practices to practical work only (Bevins & Price, 2016). The propositions in the literature support the findings of this study as the participant teachers indicated that they received some support from subject advisors, but the support was arguably insufficient. According to the findings of this study, subject advisors visited some of the teachers at their schools and offered them assistance during workshops. The assistance was, however, not sufficient to prepare the teachers to implement IBL. Henry attested to intervention programmes by subject advisors that were meant to improve teachers' IBL practices. However, the explanation showed no evidence of the programmes being IBL-inclined. He reported that the subject advisor visited the school to give guidance on IBL practices, but generally referred to the workshops as focusing on scientific investigations, which does not automatically mean they were in line with the basic tenets of IBL.

Patience shared similar experiences of subject advisors' roles in her IBL-related professional development. She confirmed the subject advisor played some role in her IBL professional development. The explanation was, however, ambiguous, because she only said the subject advisor explained in a workshop how teachers should carry out scientific investigations. Andy mentioned that she needed assistance from the subject advisor, because she had doubts about her knowledge of IBL practices and pedagogy. Overtly stating that she contemplated requesting assistance from the subject advisor implicitly suggested that she had not received much of any form of IBL-related assistance from the subject advisor.

d) **Discussions with other teachers**

Two of the participant teachers referred to interaction with other teachers at their school (Linda and Andy, of the former Model C school). These colleagues were more experienced life sciences and physical sciences teachers who also possessed knowledge of IBL pedagogy. The participants claimed that these interactions contributed to their knowledge of IBL and how to implement it. However, Linda also reflected on how other teachers had a negative effect on her choice to employ IBL in her teaching. She argued that not all teachers who had been teaching longer than she had advocated IBL pedagogy, and they are not willing to support anyone who intended to. She stated that such teachers assertively discouraged their colleagues from using IBL and claimed that it was not an ideal pedagogical approach to life sciences teaching.

5.3.3.3 Policies

This study focused on stipulated content and the language of instruction as the two main aspects of policies. In their practices of IBL, the participant teachers experienced stipulated content and language of instruction differently in their classes.

a) Stipulated content

Internationally, literature reveals that teachers are not given the latitude to decide on what to teach; instead, the content they have to teach and how they should administer assessment is stipulated for them (Ssempala, 2017). Findings by Kang and Keinonen (2016) reveal that, all over the world, teachers do not practice IBL because tight curricula do not allow them sufficient time to implement it. In the South African context, literature indicates that there is no flexibility in the science curriculum under CAPS, which means it is not easy for teachers to implement IBL maximally because they have to implement it in a rigid curriculum that has to be completed within set time frames (Dudu, 2014b). The findings of this study are similar to the findings reported in the literature. Participant teachers in this study explained that they had to implement IBL in a curriculum that did not allow flexibility with regard to what life sciences content teachers had to teach they could only teach what the curriculum approved and life sciences teachers were not permitted to make any changes.

b) Language of instruction

Internationally, literature reports that IBL helps learners develop sound language communication skills, because they communicate with each other while they conduct investigations (Kuhlthau, 2010). This, however, does not support the findings of this study, because some of the participant teachers claimed that their IBL practices were negatively affected by language barriers. In most South African high schools, life sciences is offered in English, and in some schools, in Afrikaans. As a science subject, life sciences widely refers to various scientific concepts. Two participant teachers (Henry and Patience) stated that their learners found it difficult to understand the language of instruction of life sciences, partly because the learners were second-language speakers of English, and because they are not familiar with the concepts used in life sciences, which translates into their poor performance in life sciences.

Similarly, Patience ascribed difficulties she experienced in implementing IBL successfully partly to the language of life sciences. Learners were unable to identify with the concepts that are used in life sciences, because these terms were not used in their everyday lives. Conducting scientific investigations was, therefore tremendously challenging, because the learners first needed to understand the language of the subject, before they could conduct the intended activities. She claimed that learners struggled to comprehend life sciences content, which also caused challenges regarding the implementation of IBL in Patience's classroom practice.

The two other participating teachers did not explicitly refer to language issues affecting their IBL practices. However, Linda implicitly suggested that, when she conducted scientific investigations, she had to explain language constructs, such as the meaning of the words used in the steps followed in conducting IBL, and the meaning of certain punctuation marks. This indicated that the language of instruction and the concepts used in life sciences were not always easy for learners to comprehend.

5.4. LIMITATIONS OF THE STUDY

The collection of data for the present study was affected by the time of the year it was implemented. The data was collected in the third term of the South African curriculum. Since most participants have strong beliefs regarding practical work for guided/scaffolded inquiry, not many such activities were possible during this term, as teachers largely follow the stipulations of the life sciences CAPS regarding the frequency of inquiry-inclined activities. Most of the prescribed practical work that teachers could conduct as IBL activities is done in the first and second terms. Additionally, the third term is the busiest time of the year, and teachers turn their focus to concluding the year and utilising as much time as is available to prepare Grade 12 learners for the trial examination that precedes the final examination. A future study could consider collecting data at the beginning of the year (term one), to increase the time available for data collection.

Another limitation was that the study targeted any life sciences teachers who practised IBL, and did not focus specifically on a group of teachers who taught life sciences in a certain grade. Most participants, as a result, taught Grade 12 life sciences, and indicated that their curriculum was not sufficiently flexible to allow them to promote a sound implementation of IBL in their teaching. Much of the focus in their context was teaching conventionally what the learners would be assessed on in the year-end examination. A similar study in the future could focus on teachers who teach life sciences in Grades 10 or 11, as the life sciences curriculum in these grades stipulates a substantial number of activities that allow for a maximum implementation of IBL activities.

Furthermore, the study was conducted in three government high schools with three different contexts. However, the schools all followed the same curriculum, and were under the mentorship of the same subject advisor; hence, some of the observed lessons were on the same content and topic. These findings, as a result, apply directly to this group of life sciences teachers in the same circuit. It is recommended that a similar study carried out in the future should include participants at private schools, and schools in different circuits and districts, to yield findings that will represents various contexts.

Finally, unprecedented circumstances (such as teacher reluctance to design lesson plans) forced a change in data collection methods. An intention to do document analysis had to be abandoned, as the anticipated analysis of lesson plans could not take place, leaving semi-structured interviews and non-participant observation of lesson presentations as the only data collection methods used.

5.5. IMPLICATIONS AND RECOMMENDATIONS FOR PRACTICE, POLICY AND FURTHER RESEARCH

The results of this study have implications in three areas: (a) teaching practice, (b) curriculum and professional development, and (c) future research, which are discussed below.

5.5.1 Implications and recommendations for teaching practice

The South African education system is characterised by tremendous differences regarding contextual settings of schools offering life sciences. Former Model C high schools in urban areas are generally characterised by advantageous contextual factors that are favourable for the implementation and continued practice of IBL. On the other hand, high schools in townships and rural areas still have a significant backlog in terms of favourable contextual factors for effective practice of IBL pedagogy. The most challenging contextual factor was the unavailability of laboratories and, in schools that had laboratories, relevant laboratory equipment. Furthermore, there was no consistency regarding the practice of IBL in life sciences classrooms, owing to the shortage of overt and deliberate teacher professional development that was aimed at instilling and improving teachers' use of IBL in teaching life sciences.

There is a need to establish support systems to mitigate the challenges faced by life sciences teachers who practice IBL. Provincial departments of education should provide the needed support by ensuring that schools are furnished with sufficient laboratories and relevant laboratory equipment. Schools should also establish committees that will be responsible for liaising with relevant companies that could donate money and equipment to establish laboratories at schools. There must be collaboration between universities, the basic education department and schools, to capacitate life sciences educators for sound practice of IBL pedagogy.

The findings may also be useful for the implementation of IBL in the South African CAPS. This study found that the participating life sciences teachers were practising IBL, but faced challenges, as they had different conceptualisations of what IBL is – their application of its basic tenets was still uncertain. In the South African context and circumstances, the difficulties are likely to prevail and prevent learners from experiencing the benefits of IBL, as reported by literature. Curriculum developers can intervene by being deliberate and overt regarding the principles of IBL practices teachers should implement. Content workshops organised by the education department should be aimed at capacitating teachers with knowledge of IBL practices, and should provide examples of how IBL lessons should be conducted.

Furthermore, the study has implications for the practice of teacher education in university programmes. The study found that the participant teachers had not received sufficient training to implement IBL, since their university experiences were not overtly aimed at capacitating them with IBL-related teaching methodologies. Universities should, therefore, ensure their curricula include methodologies that focus largely on training life sciences teachers to implement IBL pedagogy. Such curricula should sensitise teachers about all the strands of IBL, so that they can autonomously choose the strands that are most effective in ensuring high levels of inquiry by learners.

5.5.2 Implications and recommendations for policy

The findings of the present study have implications for teacher education, school curriculum implementation and higher education in general. Curriculum developers in the Department of Basic Education should be explicit with regard to encouraging the integration of IBL in the teaching of life sciences. The findings of the study reveal that the participant life sciences teachers had to expedite the teaching of a congested curriculum, because of the limited time available for teaching all the content. Furthermore, the rigidity of the curriculum did not allow for effective implementation of IBL. Curriculum developers should intervene by revisiting the content to be taught in life sciences, and allow more teacher autonomy regarding the choice of teaching methodology that will promote the implementation of IBL activities.

The Department of Basic Education should provide clear guidelines for in-service teachers on how they should implement IBL. The guidelines should be grade-specific and ensure the highest level of implementation in lower grades, including the Grades 8 and 9 natural sciences, which provide a foundation for life science in Grades 10 to 12. Teachers should be prepared sufficiently, by ensuring that they understand the tenets of IBL, which should be achieved by integrating Department of Basic Education workshops and intervention by experts from universities.

5.5.3 Implications and recommendations for future research

In the section on limitations for the study (Section 5.4), a few recommendations were made in relation to future research in the area of interest. In addition to those recommendations, a longitudinal study, mainly using a mixed-methods research methodology, is recommended. In addition to the advantages of qualitative research, the quantitative data collected through a mixed-methods research project could yield results that are informative and generalisable, which will maximise the relevance and applicability of the findings for guiding curriculum development.

The present study used guided/scaffolded inquiry as a conceptual framework and it was guided by social constructivism as a theoretical framework. We now understand that IBL in life sciences teaching and learning involves teachers playing a role of supporting learners from behind, thereby affording learners opportunities to take full control of their own learning and knowledge construction. Future research should broaden the focus and include other strands of IBL, particularly those that involve high levels of inquiry in life sciences lessons and which broaden the focus beyond merely practical work.

The study mainly revealed that there was no evidence of teacher professional development of the participant teachers to encourage implementation of IBL. A future study in the area of IBL could focus on investigating how curricula at South African universities incorporate teacher training in relation to IBL pedagogy specifically. Other major contributors to teacher professional development that are planned by education departments could also be investigated to establish how the department intends preparing life sciences teachers for IBL.

5.6. CONCLUSIONS

Education systems in the world, including the South African basic education system, are gradually employing pedagogical approaches that accommodate IBL in the teaching of science subjects in general, and life sciences in particular. The study found that there was some evidence of relevant teacher training in IBL among the participant teachers.

Furthermore, the teachers only practised IBL in the form of practical work at and the strand of IBL they practiced was structured inquiry.

The introduction of IBL in life sciences teaching and learning has been aimed at obliterating traditional ways of teaching, which involve the teacher taking a frontline, more active role, and which relegates the learner to the passive role. Literature hails the efficacy of IBL in eliciting desired results, which are reflected in improved learner academic achievement and more learner enthusiasm for learning life sciences. It is promising to see life sciences teachers upholding the necessity of integrating IBL in their teaching, and exhibiting a desire to improve their knowledge and practice in the area significantly. However, a lack of appropriate teacher professional development in the area of IBL by universities results in a backlog regarding its effective implementation. Interventions by the Department of Basic Education also seem to be failing to ensure that teachers conceptualise the real nature of IBL and to guide them regarding the way they should implement it in the classroom.

Furthermore, interventions should be welcomed by various entities, such as private companies, and the Department of Basic Education, to improve South African school settings, in an attempt to prepare them to optimise IBL implementation. Contextual factors pose a threat to IBL implementation in life sciences teaching, because most schools do not have the required infrastructure and resources to practice IBL. The envisaged interventions should focus primarily on improving this state of affairs and getting schools ready for IBL implementation, to ensure that the primary goal of IBL, which is producing learners who will think and operate as scientists, is achieved.

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APPENDIX A : INTERVIEW PROTOCOL

Semi-structured interview schedule for teachers

Adapted from M. Tsakeni – The influence of teacher professional identity on Inquiry-based laboratory work in school chemistry

1. Opening
    a. (Establishing rapport) My name is Lucky Ncala. I am a Masters student at the University of the Free State. I appreciate that you agreed to take part in this interview; thank you very much.
    b. (Purpose) I would like to ask you some questions on your practice as a teacher in life sciences classrooms.
    c. (Motivation) I intend to use this information in the research I am conducting concerning the implementation of inquiry-based learning in life sciences classrooms.
    d. (Timeline) This interview is anticipated to take place in 60 minutes.

2. Body

Background information

1. For how many years have you been a teacher?
2. For how long have you been teaching life sciences?
3. Which experiences have you had regarding the teaching of life sciences in the context of your school?
4. Do you think your professional training has prepared you adequately for the kind of work you do in the teaching of life sciences?
5. Which of the past experiences in terms of workshops and classroom and laboratory activities have had a significant impact on your current practice?

6. Do you think the exposure you have had in teaching life sciences has been sufficient in preparing you for your current practice? If not, in what ways do you feel the experiences would have been enhanced?

Current experiences

1. What does the Curriculum and Assessment Policy Statement stipulate about how scientific investigations should be conducted in life sciences?
2. How often, according to the CAPS document, should learners engage in scientific investigation activities in a term? Have you been able to conduct them? Have you been able to conduct more than the stipulated number of such activities? Have you found yourself being unable to conduct such stipulations? If yes, what are the reasons?
3. What role does laboratory work and scientific investigations play in your teaching of life sciences?
4. Do you find any value in the continued conduction of scientific investigations?
5. What challenges have you faced in conducting scientific investigations and practical work in your teaching of life sciences
   a) on the part of learners and
   b) within school settings?
6. How have you managed to overcome the challenges?
7. Have you had any kind of support in terms of how scientific investigations should be part of your teaching?
8. What kind of other support do you feel is required to enhance your practice regarding conducting scientific investigations?

Inquiry-based life sciences teaching practice

1. How do you prepare yourself and the learners before you conduct a scientific investigation?

2. What type of support do you give to learners before, during and after the scientific investigation?
3. What kind of support do you need when preparing and conducting the investigation?
4. If we say that inquiry involves posing a question, writing the procedure and providing the solution:
    a) What is your role and the role of the learners in posing the question?
    b) What is your role and the role of the learners in constructing the procedure of the scientific investigation?
    c) What is your role and the role of the learners in giving the solution to the problem?
5. What is your and the learners' roles in formulating the hypothesis, conducting the scientific investigation, drawing up the conclusions and communication of the findings?
6. Do you feel IBL is necessary in the teaching of life sciences?
7. Do you consider yourself as sufficiently prepared to implement IBL?
8. How do you feel the current school context affects your practice of IBL
    a) In terms of the learners,
    b) Infrastructure and
    c) Relevant laboratory equipment?
9. Did you attend any workshop on the practice of IBL?

3. Conclusion

a) (Summarise) I understand that your background experiences with scientific investigations in life sciences started _________________. Currently your experiences with scientific investigations activities are as follows _______________ and as far as the practice of IBL scientific investigations is concerned you have been able to _______________.
b) (Maintain rapport) I appreciate the time you took for this interview.

c) (Action to be taken) You have provided me with all the information I need for now. Would it be all right to call you, should I have more questions to ask you?

APPENDIX B: OBSERVATION PROTOCOL

What to observe	Observation made	Recommendations
Introduction How the teacher Creates a learning environment and engages learners in the lesson		
Learning objectives Specific aims and what knowledge and skills learners have to acquire		
Specific content The content area learners to acquire at the end of the lesson		
Questions and types of questions to be raised and explored Role of the teacher and role of learners in formulation of questions (inferences, hypotheses and questions)		
Sources and resources What the teacher needs to use to get the lesson presented versus what is available		

Contextual factors Classroom context regarding (physical space where the lesson takes place, learners)		
Procedure Role of teacher and role of learners in determining the procedure		
Solution/conclusion Role of teacher and role of learners in giving the solution and drawing the conclusion		
Ongoing assessment How the teacher assesses for teaching and intends to determine learner competencies		
Consolidation Conclusion at the end of the lesson		

APPENDIX C: LETTER TO TEACHERS

Lucky Ernest Ncala

10 Berg Street

Standerton

2430

20 March 2019

life sciences Educator

INVITATION TO PARTICIPATE IN A RESEARCH STUDY

Dear Sir/Madam

My name is Lucky Ncala and I am presently studying for a master’s degree with the University of the Free State. As part of my studies, I am conducting a research study entitled:

Case studies of inquiry-based instruction in life sciences classrooms of selected high schools in Standerton.

The purpose of the study is to explore how inquiry-based science education is practised in life sciences classrooms. I am particularly interested in the teacher practices in the classroom, teacher perceptions of inquiry-based instruction and contextual factors under which it is implemented in life sciences classrooms. The data collection will be followed by a research report, which will be made available to the schools in Standerton. The study has a potential to benefit life sciences teachers, as they will gain insight to how inquiry-based instruction can be incorporated in their teaching, following research findings attesting to its efficacy in the teaching of science subjects.

The study will involve (i) interviews with life sciences teachers at their schools, (ii) reading and analysing of their lesson preparations and (iii) observation of lessons presented by the four selected teachers at their respective schools. The interviews will take 45 to 60 minutes and the lesson observations will take 60 minutes.

I undertake to observe confidentiality and to protect participants from physical and/or psychological harm. No names of the schools and /or persons shall be used in any reports of the research. Your participation is entirely voluntary and you may withdraw at any time should you so wish.

The final results will be shared with various schools and other interested parties, including life sciences educators, which will enhance their conceptualisation of inquiry-based instruction.

If you need any further information and /or have suggestions, please do not hesitate to contact me and / or my research supervisor Dr Maria Tsakeni on TsakeniM@ufs.ac.za or +2778 640 3218

I hope that my request will reach your favourable consideration.

Yours sincerely

Lucky Ernest Ncala

Cell> +2778 512 2483 / +2772 528 2219 (email: luckyncala@gmail.com)

APPENDIX D: LETTER TO PRINCIPALS

Lucky Ernest Ncala

Cell: 0785122483

Email: luckyncala@gmail.com

26 March 2019

Dear Principal

My name is Lucky Ncala. I am a Masters student with the University of the Free State. As part of my Master of education program, I am required to conduct research on an aspect of interest with a view to making a contribution to our knowledge and understanding of the issue under study. The title of my research project is:

Case studies of inquiry-based instruction in life sciences classrooms of selected high schools in Standerton

The purpose of the study is to explore how inquiry-based science education is practised in life sciences classrooms. I am particularly interested in the teacher practices in the classroom, teacher perceptions of inquiry-based instruction and contextual factors under which it is implemented in life sciences classrooms. The data collection will be followed by a research report, which will be made available to the schools in Standerton. The study has a potential to benefit the principals of the schools offering life sciences, as teachers will gain insight to how inquiry-based instruction can be incorporated in their teaching, following research findings attesting to its efficacy in the teaching of science subjects.

The study will involve (i) interviews with four teachers at their schools, (ii) reading and analysing of their lesson preparations and (iii) observation of lessons presented by the four selected teachers at their respective schools. The interviews will take 45 to 60 minutes and the lesson observations will take 60 minutes.

I undertake to observe confidentiality and to protect participants from physical and/or psychological harm. No names of the schools and /or persons shall be used in any reports of the research. All participants will be asked to participate voluntarily in the study and may withdraw at any time should they so wish.

Upon completion of the study, I undertake to provide written reports to the department of education in the Gert Sibande District and Lekwa West and East, respectively. I will also share the findings with the high school teachers, particularly those who are offering life sciences.

If you need any further information and /or have suggestions, please do not hesitate to contact me and / or my research supervisor Dr Maria Tsakeni on TsakeniM@ufs.ac.za or +2778 640 3218

Thank you for your kind consideration to my request.

Yours sincerely

Lucky Ernest Ncala

Cell> +2778 512 2483 / +2772 528 2219 (email: luckyncala@gmail.com)

APPENDIX E: LETTER TO THE DEPARTMENT OF EDUCATION

Lucky Ernest Ncala

P.O. Box 630

Standerton

2430

20 March 2019

The Circuit Manager Lekwa West

Department of Education

Re: Request for permission to carry out research in Lekwa West and Lekwa East Circuits

I hereby request for permission to conduct research at selected high schools Lekwa West and East, which are in Standerton.

My name is Lucky Ncala, and I am presently studying for a Masters in Curriculum Studies with the University of the Free State. As part of my Master of education program, I am required to conduct research on an aspect of interest with a view to making a contribution to our knowledge and understanding of the issue under study. The title of my research project is:

Case studies of inquiry-based instruction in life sciences classrooms of selected high schools in Standerton

The purpose of the study is to explore how inquiry-based science education is practised in life sciences classrooms. I am particularly interested in the teacher practices in the classroom, teacher perceptions of inquiry-based instruction and contextual factors under which it is implemented in life sciences classrooms. The data collection will be followed by a research report, which will be made available to the schools in Standerton. The study has a potential to benefit the principals of the schools offering life sciences, as teachers will gain insight to how inquiry-based instruction can be incorporated in their teaching, following research findings attesting to its efficacy in the teaching of science subjects.

The study will involve (i) interviews with four teachers at their schools, (ii) reading and analysing of their lesson preparations and (iii) observation of lessons presented by the four selected teachers at their respective schools. The interviews will take 45 to 60 minutes and the lesson observations will take 60 minutes.

I undertake to observe confidentiality and to protect participants from physical and/or psychological harm. No names of the schools and /or persons shall be used in any reports of the research. All participants will be asked to participate voluntarily in the study and may withdraw at any time should they so wish.

Upon completion of the study, I undertake to provide written reports to the department of education in the Gert Sibande District and Lekwa West and East respectively. I will also share the findings with the high school teachers, particularly those who are offering life sciences.

If you need any further information and /or have suggestions, please do not hesitate to contact me and / or my research supervisor Dr Maria Tsakeni on TsakeniM@ufs.ac.za or +2778 640 3218

Thank you for your kind consideration to my request.

Yours sincerely

Lucky Ernest Ncala

Cell> +2778 512 2483 / +27528 2219 (email: luckyncala@gmail.com)

APPENDIX F: LEKWA EAST CIRCUIT RESEARCH APPROVAL LETTER

education
DEPARTMENT: EDUCATION
MPUMALANGA PROVINCE

LEKWA EAST CIRCUIT
P/BAG X 2015
STANDERTON
2430

C/N KERK BURGER STR.
STANDERTON
2430
Telephone number: (017) 712 1282
Facsimile number: (017) 712 1283

Litiko le Temfundvo wezeMfundo | Umnyango WezeMfundo | Departement van Onderwys | Umnyango

REF: MRS. S.M. BOHATA | TEL: 017 712 5691 | E-mail: lekwaeastcircuit@gmail.com

TO: L.E NCALA
UNIVERSITY OF THE FREE STATE

FROM: MRS. S.M BOHATA
CIRCUIT MANAGER
LEKWA EAST CIRCUIT

SUBJECT: PERMISSION TO CARRY OUT RESEARCH IN LEKWA EAST CIRCUIT

DATE: 06 JUNE 2019

The above mentioned Circuit grants you permission on your research project titled: Case studies of inquiry-based instruction in life sciences classrooms of selected high schools in Standerton.

We wish you all the luck and future endeavours in your studies.

We hope that your recommendations will be of utmost importance in assisting life sciences in classrooms and the entire education fraternity.

Thank you

Yours in Education

S.M Bohata
Circuit Manager

APPENDIX G: ETHICS STATEMENT

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS UV

GENERAL/HUMAN RESEARCH ETHICS COMMITTEE (GHREC)

01-Jun-2019

Dear Mr Ncala, Lucky LE

Application Approved

Research Project Title:
Case studies of inquiry-based instruction in life sciences classrooms of selected high schools in Standerton

Ethical Clearance number:
UFS-HSD2019/0396/0106

We are pleased to inform you that your application for ethical clearance has been approved. Your ethical clearance is valid for twelve (12) months from the date of issue. We request that any changes that may take place during the course of your study/research project be submitted to the ethics office to ensure ethical transparency. furthermore, you are requested to submit the final report of your study/research project to the ethics office. Should you require more time to complete this research, please apply for an extension. Thank you for submitting your proposal for ethical clearance; we wish you the best of luck and success with your research.

Yours sincerely

Dr. Petrus Nel
Chairperson: General/Human Research Ethics Committee

[illegible] Nelson Mandela Drive/Rylaan
Park West/Parkwes
Bloemfontein [illegible]
South Africa/Suid-Afrika

P.O. Box/Posbus 339
Bloemfontein 9300
South Africa/Suid-Afrika
T: +27(0)51 401 [illegible]
F: +27(0)51 401 [illegible]
[illegible]
www.ufs.ac.za

APPENDIX H: LANGUAGE EDITING

Declaration

15 October 2020

PO Box 4
Otjiwarongo
Namibia

Student: Lucky Ernest Ncala

Thesis: Case studies of inquiry-based instruction in life sciences classrooms of selected high schools in Standerton

I confirm that I edited this thesis, checked the references and recommended changes to the text.

MA Language Practice

Hettie Human
WRITER | EDITOR | TRANSLATOR | INTERPRETER

+264 813 359 120 | hettie.human@gmail.com

APPENDIX I: PLAGIARISM REPORT

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- ID: 1419083688
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Dissertation By Lucky Ncala

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