THE EFFECTS OF AN INQUIRY-BASED TEACHING APPROACH ON THE GRADE 10 LEARNERS' CONCEPTUAL UNDERSTANDING OF CHEMICAL CHANGE TOPIC IN PHYSICAL SCIENCES

by

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The effects of an inquiry—based teaching approach on the Grade 10 learners' conceptual understanding of chemical change topic in Physical Sciences

I declare that the above dissertation is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

I further declare that I submitted the dissertation to originality-checking software and that it falls within the accepted requirements for originality.

I further declare that I have not previously submitted this work, or part of it, for examination at Unisa for another qualification or at any other higher education institution.

(The dissertation will not be examined unless this statement has been submitted).

09/12/2022

SIGNATURE **DATE**

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DEDICATION

I dedicate the study to my fellow Physical Sciences educators in South Africa, who are together entrusted with the task to equip our young scientists with the necessary scientific skills to prepare them to fully participate in scientific fields inspired by the fourth industrial revolution.

ABSTRACT

The study used both quantitative and qualitative methods to collect data. The quantitative part of the study used quasi-experimental design, involving pretest and posttest non-equivalent groups to determine the effects of the 5E inquiry-based approach on Grade 10 learners' conceptual understanding of chemical change topic in Physics, with the view to improve their performance in the subject. Meanwhile the qualitative aspect involved focus group interviews to determine the perception of the learners on their learning of chemical change under the inquiry-based and traditional-based learning environments. There were 142 Grade 10 Physical Sciences learners who participated in the study, 73 of which were in the experimental group, and 69 of which were assigned to the control group. Moreover, 16 learners from the control group and 16 from the experimental group who were conveniently sampled participated in the interviews. Quantitative data from the pretest and posttest, as well as qualitative data from focus group interviews, were gathered to test the null hypothesis of the study and to answer the research questions, formulated as: there is no statistical significance difference in conceptual understanding of chemical change between Grade 10 learners taught using inquiry-based approaches and those taught using the traditional teaching methods in the posttest results (tested at significance level $\alpha=0.05$). The null hypothesis was rejected, as the p value showed that $p=0.000<0.05$. The study found that, despite the improvement in the level of conceptual understanding in the posttests of both the experimental and control groups, learners taught using the inquiry based approach have a higher level of conceptual understanding than those taught using the traditional teaching approach. The interviews also found that learners taught using the inquiry-based teaching method perceive their learning environment as one that allows active learning, encourages group and individual learning, and promotes knowledge gain. The study posits that, instead of relying on traditional teaching methods, science teachers can use properly planned traditional methods together with inquiry methods in their lessons especially in cases when it is not possible to use inquiry-based teaching methods alone.

Key words: inquiry-based teaching approach, inquiry-based teaching and learning, traditional teaching methods, 5E inquiry model, conceptual understanding, chemical change, quasi-experimental design, Physical Science.

LIST OF ACRONYMS

ATP	Annual teaching plan
CAPS	Curriculum and Assessment Policy Statement
DBE	Department of Basic Education
EWF	Education World Forum
FET	Further Education and Training
GET	General Education and Training
IBTL	Inquiry-based teaching and learning
MCQ	Multiple choice question
NSES	National Sciences Education Standards
TIMSS	Trends in International Mathematics and Science Study
UNISA	University of South Africa

LIST OF FIGURES

LIST OF TABLES

TABLE OF CONTENTS

PAGE NO:

CHAPTER 1

INTRODUCTION AND BACKGROUND

1.1. INTRODUCTION

Inquiry teaching and learning in science is an approach according to which learners play an active role in their learning, and are able to improve their understanding of core concepts and learning strategies by tackling problems that challenge their thinking, and which allows them to gather evidence that subsequently enables them to understand the various aspects of the world around them (Penn, Ramnarain, Kazeni, Dhurumraj, Mavuru and Ramaila, 2021). In an inquiry-orientated Science classroom, learners play an active role in their learning, where they conduct investigations, perform experiments, ask questions, and make observations to solve problems; in so doing improving their critical thinking skills and their understanding of science concepts (Gyamphoh, Aidoo, Nyagblormase, Kofi and Amoako, 2020). According to Sutiani, Situmora and Silalahi (2021), critical thinking is necessary for conceptual understanding of scientific concepts, as this equips learners with problem-solving and discovery capabilities. Sari and Haji (2021) states that a learner who has developed a conceptual understanding of a given concept ought to be able to explain the concept in his own words, and apply it in real-life situations.

Studies by Amida and Nurhamidah (2021) and Sutiani et al. (2021) emphasise that the implementation of inquiry approaches in science classrooms improves critical thinking in learners, which is important in improving learners' conceptual understanding of core scientific concepts. Furthermore, findings of studies conducted by Bidi (2018), Mamombe, Mathabane and Gaigher (2020), Mensah – Wonkyi and Adu (2016), and Sari and Haji (2021) regarding the effect of inquiry on learners understanding concluded that learners' understanding of Science and Mathematics concepts does improve when taught with the various inquiry-based teaching and learning approaches in class. Gyamphoh et al. (2020), Njoroge, Changeiywa and Ndiraangu (2014) and Wilson (2020) also conducted studies about the effect of inquiry on learners' achievement in Science, and concluded that the implementation of inquiry-based approaches in a science classroom does not only improve their critical thinking skills and conceptual understanding, but also results in an improvement on the learners' achievement in Science.

According to Bidi (2018), just like elsewhere in the world, South African learners are performing poorly in scientific subjects, specifically in Mathematics and Physical Sciences, where as a result, fewer learners are able to achieve the required grades in these subjects to qualify to enroll for a critical skill qualification at the university. The poor enrollment of learners in critical skill qualifications is the reason for the current shortage of science graduates in critical skills like medicine and engineering, with a huge backlog of about 1200 engineers per year in the various engineering fields required to meet the demand of the labour market (Bidi, 2018).

Despite the government's commitment to improving school conditions by increasing school budgets, providing skills development for teachers and equipping schools with science laboratories, science learners continue to perform more poorly than expected in Physical Science and Mathematics (Mupira and Ramnarain, 2018). In South Africa, the Physical Sciences curriculum is made up of two components, viz. physics and chemistry, and according to Mamombe et al. (2020), the poor performance of learners in Physical Sciences can be ascribed to their poor performance in the chemistry component of the Physical Sciences curriculum. Learners in primary and secondary schools generally perform poorly in Chemistry (Mamombe et al, 2020).

Chemical change, as one of the topics in Chemistry, is the most challenging topic as it has various conceptions that learners must conceptualise, thereby probing learners to think critically and engage with concepts in order to understand them (Bidi, 2018). According to the Department of Basic Education (DBE) (2011), the Grade 10 chemical change topic is made up of the following subtopics: physical and chemical change, representing chemical change, reactions in aqueous solution, and stoichiometry. Physical Science learners who have difficulty in understanding chemical change tend to perform poorly in Physical Sciences as a whole (Amida and Nurhamidah, 2021).

The difficulty experienced by learners in understanding chemical change can be understood as a result of the teaching strategies that most teachers use in their Physical Sciences classrooms (Bidi, 2018). According to Bidi (2018), Mamombe et al. (2020) and Penn et al. (2021), most Science teachers still use the traditional lecture teaching method in their classrooms, whereby the teacher does most of the talking, and very little activities that stimulate interest and engages the learners in their learning. Despite the benefits of inquiry-based teaching and learning in Science as mentioned above, and the fact that a Physical Sciences curriculum emphasises on the implementation of inquiry-based teaching and learning strategies in science classrooms, many South African teachers still use the traditional teaching methods as their preferred teaching method (Penn et al, 2021). Lack of infrastructure, lack of teaching and learning resources, poor training or workshop of teachers on the different science teaching and learning approaches, and lack of support of Science and Technology educators are some of the reasons identified that hinder the implementation of inquiry teaching and learning strategies in science classrooms (Penn et al, 2021). Traditional teaching methods negatively affect science teaching and learning, as they do not promote critical thinking and problem-solving, which constitute necessary skills for the development of conceptual understanding of core scientific concepts (Mensah-Wonkyi and Adu, 2016). According to Gyamphoh et al. (2020), science learners perceive Physical Sciences as a difficult subject because they have difficulty in understanding core concepts of the subject, and this is as a result of the traditional teaching strategies that Physical Sciences teachers still employ in their teaching.

1.2. STATEMENT OF THE PROBLEM

Despite the government's various strategies aimed at improving the performance of learners in Physical Sciences, learners continue to perform poorly in the subject (Bidi, 2018 & Penn et al, 2021). The poor performance of learners in Physical Sciences is not endemic to South African learners, but also affects learners in many countries around the world (Bidi, 2018 and Penn et al, 2021).

According to Bidi (2018) and Mamombe et al. (2020), one of the factors leading to learners' poor performance in Physical Sciences is their poor performance in the Chemistry part of Physical Sciences, which is caused by the learners' poor conceptual understanding of the fundamental concepts of chemistry. Bidi (2018) and Amida and Nurhamidah (2021) describe chemical change as one of the most difficult topics to understand in chemistry. Learners who developed a conceptual understanding of chemical change are likely to perform better in Physical Sciences, as this develops learners' critical thinking skills (Amida and Nurhamidah, 2021). Learners' poor conceptual understanding of chemistry concepts is due to the fact that many Physical Sciences teachers still conduct their lessons using the traditional teaching approach which does not promote learners' critical thinking (Mamombe et al., 2020).
Therefore, the study is aimed at determining the effects of an inquiry-based teaching approach on Grade 10 learners' conceptual understanding of chemical change in Physical Sciences, with a view to improving their performance in the subject.

1.3. RATIONALE OF THE STUDY

South Africa is not producing enough science learners at the school level, due to the high failure rate in the subject (Mamombe et al., 2020; Penn et al., 2021). The high failure rate in Physical Sciences negatively affects the number of learners furthering their studies at the university level in critical skill qualifications, as such qualifications require outstanding performance in Physical Sciences and Mathematics (Bidi, 2018).

Bidi (2018) and Mamombe et al. (2020) attribute poor performance in Physical Sciences to learners' poor performance in the Physical Sciences' chemistry section, with chemical change being the most difficult topic for learners to understand in chemistry. The use of inquiry-based teaching and learning over traditional teaching methods in a science classroom showed that learners' conceptual understanding improves, and that improves their performance in the subject (Mamombe et al., 2020).

Even though various studies have been carried out on the impact of inquiry-based teaching and learning on learners' conceptual understanding (Bidi, 2018, Mamombe et al., 2020, Mensah-Wonkyi and Adu, 2016, Penn et al., 2021, Primada, Distrik and Abdurrahman, 2018, and Sari and Haji, 2021), only a few studies that I am aware of have been recently conducted in South Africa (Mamombe et al., 2020 and Penn et al., 2021). None of these studies (as far as I know) conducted in South Africa focused on the impact of inquiry on Grade 10 Physical Sciences learners' conceptual understanding. Furthermore, Grade 10 is a very important grade in the South African education system, as it is a transition grade from Senior Phase to the Further Education and Training (FET) phase (Mupira and Ramnarain, 2018). Physical Science learners in a transition grade like Grade 10 need to be equipped with the necessary skills and motivation to ensure that they perform better in the subject in the current grade and beyond (Mupira and Ramnarain, 2018). Given the above deliberations, the study is necessary to determine the effects of an inquiry-based teaching approach on Grade 10 learners' conceptual understanding of chemical change concepts in Physical Sciences, with a view to improving their performance in the subject.

1.4. AIM

The aim of this study is to determine the effects of an inquiry-based teaching approach on the Grade 10 learners' conceptual understanding of chemical change in Physical Sciences, with the view to improving their performance in the subject.

1.5. THE OBJECTIVES OF THE STUDY

The objectives of the study are to:

I. Determine the effects of an inquiry-based teaching approach on the Grade 10 learners' conceptual understanding of chemical change concepts in Physical Sciences.
II. Determine learners' perceptions on their learning of chemical change under the inquiry-based approach and the traditional based approach classroom environment.

1.6. RESEARCH QUESTIONS

The main research question of the study is:

What are the effects of the inquiry-based teaching approach on the Grade 10 Physical Science learners' conceptual understanding of chemical change and their performance in the subject in comparison with the traditional teaching methods? The sub- questions of the research are:

I. What are the effects of an inquiry-based teaching approach on the Grade 10 learners' conceptual understanding of chemical change concepts in Physical Sciences in comparison with the traditional teaching approach?
II. What are the learners' perceptions on their learning of chemical change under the inquiry-based approach and the traditional based approach classroom environments?

1.7. HYPOTHESIS

The null hypothesis of the first research question is:

H_0 = There is no statistically significant difference in conceptual understanding of chemical change between Grade 10 learners taught with an inquiry-based teaching approach and those taught with the traditional teaching approach in the posttest results.

The alternative hypothesis for the null hypothesis is:

H_A= There is statistically significant difference in conceptual understanding of chemical change between Grade 10 learners taught with an inquiry-based teaching approach and those taught with the traditional teaching approach in the posttest results.
The null hypothesis was tested at significance level, **$\alpha = 0.05$**

1.8. METHODOLOGY AND DESIGN

The research methodology provides an outline of the procedures to be followed in pursuit of answers to the identified problem/s (Chivanga and Monyai, 2021). This section describe in detail the research design, population and sampling methods, the techniques for data collection, as well as data analysis and interpretation techniques employed by the research to answer the study research questions (Nayak and Singh, 2015).

The study followed a quasi-experimental design involving pretest-posttest non-equivalent groups. The quasi-experimental design pretest-posttest was used together with focus group interviews to investigate the effects of an inquiry-based teaching approach on Grade 10 learners' conceptual understanding of chemical change in Physical Sciences. Convenience, purposive and simple random sampling techniques were employed to select the appropriate sample and research area, and to assign the four sampled school classes into the control group and experimental group. Quantitative and qualitative data gathering and analysis methods were used to gather and analyse the data collected from the tests and focus group interviews, respectively.

1.8.1 Research design

The study followed the quasi-experimental design, involving the pretest-posttest non-equivalent groups. According to Mensah-Wonkyi and Adu (2016), quasi-experiments are descriptive studies that seek to estimate the degree to which an intervention affected a population of interest. This kind of research design is a type of experimental design that is mostly used when it is not possible to randomly assign the participants (Gribbons and Herman, 1997). It is normally not possible to separate learners in secondary school classes, since they exist as intact groups, and school principals would not allow learners to be rearranged for research purposes, since this would disturb teaching and learning (Njoroge et al., 2014). Even though non-equivalent groups were used in this study, a control group that is as equivalent as possible to the experimental group in terms of characteristics was used, so to ensure that the end results were entirely due to the treatment given to the experimental group (Gathage et al., 2021). A quasi-experimental design is frequently used in studies that evaluate the impact and effectiveness of a certain programme or teaching strategy, for example, it can be used by a teacher who has two teaching methods to choose from, so as to determine a teaching method that would be more effective in his/her subject or topic in class (Gribbons and Herman, 1997). In the quasi-experiment pretest-posttest non-equivalent groups design, the control group and experimental group are first given a pretest to assess the variation in the groups (Gribbons and Herman, 1997). After the pretest, the experimental group is then given a treatment, and thereafter both groups are subjected to a posttest (Njoroge et al., 2014). The researcher will then conclude based on the posttest results whether the treatment had any effect on the research, subsequently initiating a cause and effect relationship (Njoroge et al., 2014).

The study used both quantitative and qualitative data gathering and analysis methods. Qualitative data collection and analysis methods were utilised to determine the Grade 10 learners' perspectives on their learning of chemical change under the inquiry-based approach and the traditional approach environments. The findings of the interviews were interpreted in conjunction with those of the pretest and posttest.

Interviews were carried out at the end of the study so as to provide a qualitative account for the relationship (if any) quantitatively found to exist between the inquiry-based teaching approach and conceptual understanding (Mensah-Wonkyi and Adu, 2016). According to Golafshani (2003), the goal of a qualitative approach is to understand a social phenomenon by engaging in methods such as interviews, observations, and etc. to produce data in a form of words that can be analysed qualitatively. The strength of this approach lies in the fact that data is collected from subjects of interest in their changing natural setting, which allows the researcher to be there to capture the moment before and after the change occurs (Golafshani, 2003). According to Daniel (2016), the involvement of the researcher as a research instrument in the qualitative approach, makes this approach suitable for studying the feelings, thoughts, reasoning, attitudes, and etc. of the participants in detail. Furthermore, qualitative data gathering and analysis methods can

be used in conjunction with the quantitative approach to explain the findings obtained quantitatively (Bidi, 2018).
During the quantitative approach, quantitative data was generated, collected and analysed using quantitative methods (Blyth, 2010). According to Nayak and Singh (2015), quantitative research is a research approach that collects and statistically analyses numerical data. A quantitative approach can be used in inferential research, where a hypothesis is tested so as to provide an explanation about a topic or statement instead of just describing it (Sukamolson, 2007). Moreover, Chivanga and Monyai (2021) describe quantitative research as a research approach that uses clearly stated hypotheses to prove or disprove a theory and it focuses mostly in causal relationships. The strengths of this kind of research approach include the use of statistical data analysis methods, which save time and resources. The scientific nature of quantitative approach makes it possible to generalise research findings from a sample to the entire population, the use of control groups increases the validity of quantitative research, and, furthermore, the absence or minimal interaction between the researcher and the participants reduces the possibility of researcher biases when collecting or analysing the data (Daniel, 2016).

The null hypothesis of the study is that there is no statistically significant difference in conceptual understanding of chemical change in Grade 10 learners taught with an inquiry-based teaching approach, and those taught with the traditional teaching methods in the posttest results; while the alternative hypothesis states that there is statistically significant difference in conceptual understanding of chemical change in Grade 10 learners taught with an inquiry-based teaching approach, and those taught with the traditional teaching methods in the posttest results.

A dependent variable is a variable whose change the researcher wants to explain, and an independent variable is a variable that assists in providing reasons for the change in the dependent variable (Patel, 2009). In this study, the independent variables refer to an inquiry-based teaching approach and the traditional teaching methods, because these variables will be used to explain the change (if any) of the dependent variable. The dependent variable in the study is conceptual understanding of the learners.

1.8.2 Study area

The study was conducted in four schools around Kanyamazane Township and Msogwaba Trust. All the schools are within the Mbombela Local Municipality, in the Ehlanzeni School District, Mpumalanga Province. The study focused on 142 Grade 10 learners, specialising in Physical Sciences from four different high schools. The data collection period was aligned with the allocated time of chemical change (physical and chemical change, and representing chemical change) on the work schedule of the Physical Sciences CAPS document so as to ensure that there was minimal disruption (if any) of lessons so as to avoid any loss of tuition time. Four Physical Sciences teachers of the selected schools and classes were part of the study. The use of teachers of the selected schools served to avoid disruptions of the lessons, and to ensure that the teaching and learning environment was as normal as possible.

1.8.3 Population and sampling

Chivanga and Monyai (2021) define a sample as a small representative group of the entire population of interest, which is selected in cases where it is not possible to conduct a study with the entire population. Purposive sampling was used to select four high schools of interest (Mamombe et al., 2020). The schools were selected from a population of interest of about 20 high schools from Lekazi Township and Msogwaba Trust in Ehlanzeni School District, which offers Physical Sciences in Grade 10. Maree (2007) describes purposive sampling as a non-probability sampling technique, whereby the researcher only selects participants who 'fit' in his particular idea of the purpose of the study. This sampling method allows the researcher to use his own knowledge of the study to select features that will assist in providing answers to the question/s of the study (Nayak and Singh, 2015). Moreover, Purposive sampling was employed to select four high schools that have one Grade 10 Physical Science class, one science teacher, are no-fee-paying schools, have semi-furnished laboratories, and have about 40 learners in the science class. Such conditions were to ensure that all the learners were exposed to similar conditions before the treatment. This was done so as to avoid the effect of variables other than the one being tested, and to avoid threat to internal validity of the study (Njoroge et al., 2014). The four schools were randomly assigned into the experimental and control group, unbeknownst to the learners (Mensah – Wonkyi and Adu, 2016). Therefore, in total, there were two classes in the experimental group, and two classes in the control group. According to Nayak and Singh (2015), in simple random sampling, everyone in the population has an equal chance of being selected, where as a result, this kind of sampling technique eliminates sample bias that may pose a threat to the validity of the study. The learners in the control group were taught using the traditional teaching methods, while those in the experimental group were taught using an inquiry-based teaching approach (Mamombe et al., 2020). The total sample size of the study was 142, 69 from the two control group classes, and 73 from the two experimental group classes from the four high schools. The sample size is considered to be adequate for the study, since constraints such as hypothesis testing, funding availability, and period of study were taken into consideration when determining the sample size (Nayak and Singh, 2015). Thirty-two learners participated in the focus group interviews at the end of the study; 16 (in groups of 8) were from the experimental group, and 16 (in groups of 8) were from the control group. According to Bidi (2018), the number of participants is not as important in a qualitative approach as in quantitative approach, since the former focuses on the perspective, feelings, and attitudes of the participants.

Factors such as race, gender, and age of the learners were not taken into consideration when selecting the sample size as the rationale of the study focuses only on the effects of inquiry-based approach on Grade 10 learners' understanding of chemical change in Physical Sciences.

1.8.4 Data collection

Quantitative data was collected from the results generated from the pretest and posttest administered to the control and experimental groups to answer the first research question (Mensah-Wonkyi and Adu, 2016). The responses of the learners in the focus group interviews after the posttest made up the qualitative data, which was analysed to answer the second research question, and to also triangulate the findings of the quantitative approach.

The participants in the four classes from four schools were subjected to a pre-test, which was then followed by an hour-long lesson on physical and chemical change, and representing chemical change for two weeks as stipulated in the Physical Sciences work schedule. The participants in the two classes of the control group were taught using the traditional teaching methods, while participants in the two classes of the experimental group were taught using an inquiry-based teaching method, which constituted the treatment of the study (Gathage et al., 2020). The post-test was then written by both groups at the end of the lessons, and scripts marked and recorded by the researcher. Below are the data collection procedures and instruments:

- **Pilot study -** According to Ochieng (2009), a pilot study refers to a process of checking whether the research gathering instruments are fit for purpose before they could be used in the actual study. Meanwhile, Dikko (2016) posits that a pilot study constitutes a pre-test, which is conducted on participants with similar characteristics as those in the actual study, in order to determine and rectify any challenges with the data gathering instrument, before it could be used in the actual study. In the current study, a pilot study was conducted with 35 Grade 10 learners and three teachers from two schools, which were not part of the study. The learners were given the test to write, so as to determine whether the test measured conceptual understanding as it was supposed to, and to detect any mistakes in the questions. Meanwhile, the teachers were given a task to determine whether the test questions were appropriate and understandable to the learners. Furthermore, eight of the 35 learners were asked interview questions so as to check if they were understandable, could be answered in one hour, and measured the perceptions of the learners as they were supposed to.
- **Tests** – the participants in both the experimental group and the control group wrote a pre-test and post-test comprising of 10 multiple choice questions (MCQ) of 20 marks each related to physical and chemical change, and representing chemical change subtopics in chemical change. The test questions were designed according to the conceptual understanding indicators identified by Makhrus, Wahyudi and Zuhdi (2021): (I) interpreting; (II) classifying; (III) inferencing; (IV) comparing; and (V) explaining. The posttest MCQ questions were exactly the same

as the pretest questions. The researcher marked and recorded the tests marks in designated marksheets that divides the marks in groups of five according to the five indicators as identified by Makhrus et al. (2021).

- **Lesson plan intervention** – the experimental group lesson plan was designed according to the 5E inquiry model, which has five inquiry phases. According to Mupira and Ramnarain (2018), inquiry phases are smaller units that are connected to break down the complex scientific process of inquiry to ensure maximum support of learners and to highlight the key features of scientific inquiry. The logical connection of the inquiry phases forms an inquiry cycle (Mupira and Ramnarain, 2018). According to Mamombe et al. (2020), the 5E inquiry model consists of five phases, which are: Engage, Explore, Explain, Elaborate, and Evaluate. In the Engage phase, the teacher is required to generate ways of stimulating interest in the learners and activate their prior knowledge (Mupira and Ramnarain, 2018). Mupira and Ramnarain (2018) further state that in the Engagement phase, learners or the teacher formulate the investigative question that ought to drive the lesson, and then learners are required to predict the outcome of the investigation. The Explore phase develops from the Engagement phase, where learners are now given probing activities that provide them with experiences to develop skills and concepts (Mamombe et al., 2020). According to Warner and Myers (2017), in the Explore phase, the teacher observes and guides the learners to provide them with the necessary scaffolding. In the Explain phase, learners present their discoveries made in the Explore phase (Warner and Myers, 2017). The teacher then, after observing and guiding, correct the noted misconceptions, explain concepts, and introduces scientific terms (Mamombe et al, 2020). According to Warner and Myers (2017), during the Elaborate phase, learners make connections between new concepts, discoveries, principles, and real-world experiences, and apply them to a new situation (Warner and Myers, 2017). Unlike traditional teaching approach, the application of concepts and knowledge in this method allows learners to have an understanding of their learning (Warner and Myers, 2017). The fifth phase is the Evaluate phase. In the Evaluation phase, the teacher assesses the learners based on the objectives of the initial topic (Mupira and Ramnarain, 2018). Mamombe et al. (2020) further explain that in the Evaluation phase, learners' understanding of the concepts learned is tested, either by posttest or interviews, or both.

- **Interviews** - an interview is a conversation between the interviewer and participant/s, where the interviewer asks questions about the ideas, views, beliefs, behaviours, and opinions of the participant/s to collect the data he needs (Maree, 2007). According to Maree (2007), properly conducted interviews can assist the researcher to gather valuable qualitative data from the participants.

In this study, semi-structured focus group interviews were conducted after the participants concluded all the lessons and the posttest. According to Maree (2007), focus group interviews are interviews where a group of five to 12 people is interviewed at the same time in order to gather information about a topic of interest. Focus groups allow a researcher to gather in-depth qualitative data in a short space of time (Bidi, 2018). The focus group interviews followed a ‘funnel structure’, where the interviewer ask open-ended questions to ‘break the eyes’ of the participants (Maree, 2007). The interviews aimed to gather qualitative data on the perceptions of learners on their learning of chemical change under the inquiry-inspired and the traditional-inspired classroom environments. The use of interviews served as the supplementation and triangulation of the findings of the pretest and posttest so to provide in-depth understanding of the relationship between the inquiry-based teaching approach and the learners’ conceptual understanding. The semi-structured interviews enabled the researcher to investigate further about the perceptions of learners by allowing new ideas to emerge during the interviews (Mamombe et al., 2020). According to Nayak and Singh (2015), interviews are essential tools for collecting qualitative data that can be used with data collected with other methods to investigate or study the research problem in detail. Despite being labelled time consuming and difficult to analyse, interviews, if conducted properly can provide high data validity since data comes directly from the participants’ mouth, provide larger number of responders as it takes place on agreed time, provide flexibility to the researcher and participants, and uses easily available equipment (Nayak and Singh, 2015).

Eight learners in each class were selected in order to makeup one focus group. There were four focus groups in total, with two from the experimental group; and another two from the control group. Thirty-two learners in total participated in the focus group interviews. The interview questions were designed according to perceptions indicators designed by Mensah-Wonkyi and Adu (2016) (with additions). During the interviews, each learner was asked questions based on learners' cohesiveness, learners' co-operation, teacher support, learners' confidence in the topic, and knowledge gain. The interviews took about 60 minutes each. More time was given for the interview, so to ensure that the participants were not rushed and can freely talk about their experiences. Assigning more time for data collection in qualitative research increases the credibility and validity of the study (Cope, 2014). The interview sessions were tape-recorded, but before any recording was made, participants were made aware of the fact that the interview would be recorded (Bidi, 2018).

1.8.5 Data analysis and interpretation

The collected data was analysed using quantitative and qualitative analysis methods.

1.8.5.1. Quantitative Data Analysis

Quantitative methods were used to analyse and interpret the collected pretest and posttest results to answer the first research question. In quantitative data analysis methods, numerical data is systematically collected and evaluated using computerised or manual statistical data analysing procedures (Ameer, 2021). In quantitative data analysis, researchers are able to explain observations in a systematic and ordered approach known as descriptive statistics, and then make general conclusions about a phenomenon of interest based on the small group that has been studied (Ameer, 2021).

According to Maree (2007), there are two types of quantitative data analysis methods, namely descriptive statistics and inferential statistics.

I. Descriptive statistics

Descriptive statistics organises numerical data in the simplest form (Maree, 2007). This procedure summarises the collected data in the simplest form so to illuminate certain meaningful patterns in the data (Nayak and Singh, 2015). Furthermore, descriptive analysis methods can only make conclusions solely based on the analysed data and sample, such conclusions cannot be generalised to the entire population of interest (Nayak and Singh, 2015). According to Ameer (2021), in descriptive statistics, numerical data is collected and organised into either graphs or tables, or both. The mode, mean and median are used in descriptive statistics to locate the number or value that clearly describes the total set of values in a given set of numbers (Maree, 2007). In this study, the numerical data collected was summarised descriptively using percentages, mean and standard deviation scores, and graphs. Furthermore, the N-gain score of each conceptual understanding indicator and that of the mean score were recorded. This was done so as to determine whether there was any positive gain in the performance of that conceptual understanding indicator (Primada et al., 2018). The N-gain score is determined by getting the difference between the posttest and pretest marks. According to Meltzer (2002), a positive difference indicate that there was a positive gain in the performance, and a negative score indicate the opposite (Meltzer, 2002).

II. Inferential statistics

The percentages, mean and standard deviation scores, N-gain scores and graphs were then analysed further using inferential statistics to provide in-depth understanding of the results and be able to generalise the findings to the entire population of schools in the Mgwenya and Sikhulile circuits, and beyond. According to Maree (2007), inferential statistics provide an in-depth description of the observations made by analysing further the collected data. In this type of quantitative data analysis method, the researcher uses probability methods to gather a sample that will precisely represent the entire population of interest so that it can be possible to generalise conclusions made on the sample to the entire population (Ameer, 2021). Ameer (2021) further elaborates that this analysis approach allows the researcher to use various methods to determine whether there are any similarities or differences that cannot be easily picked up in the observations made.

The researcher used independent samples and paired samples t-test to determine if there was any statistical significance between the level of conceptual understanding of chemical change between the control group and the experimental group, and also within each group using the Statistical Package for the Social Sciences (SPSS software).

1.8.5.2 Qualitative data Analysis

Qualitative analysis was used to analyse the data collected during the interviews to determine the perceptions of the learners on their learning of chemical change under the traditional teaching method and the inquiry-based method. The data from the tape recorder was transcribed and coded based on a priori and emerging themes. According to Maree (2007), coding refers to a data analysis process in qualitative research that takes place after the organisation and transcription of the data. During this process, the researcher meticulously read through the data, word by word, and divides it into logical analytical units that are then marked with symbols or descriptive words (Maree, 2007). After the coding process, the data was divided into logical units which were then assigned to a priori and emerging themes, the data was then interpreted.

1.9. RELIABILITY AND VALIDITY

Reliability and validity are more common in quantitative research (Golafshani, 2003). Qualitative research focuses more on credibility and trustworthiness (Cope, 2014.

Ways used by the researcher to ensure validity and reliability in the quantitative and qualitative approaches are as follows.

1.9.1. Quantitative approach

Useful findings in quantitative research can only be achieved by measuring the validity and reliability of the measuring instrument (Suruca and Maslakci, 2020). All the aspects that ensured validity and reliability in the research were followed so as to ensure that useful findings were devised from this study (Suruca and Maslaci, 2020).

1.9.1.1. Validity

To ensure validity of the test that was utilised in this study as the measurement instrument, the test was developed from questions from DBE-issued previous question papers (some of them modified), and the questions were arranged according to the conceptual understanding indicators, as described by Makhrus et al. (2021). Validity determines whether the measuring instrument used in a research measures what it is supposed to measure (Ameer, 2021). The validity of an instrument can be determined by carefully analysing and interpreting the data received from the measuring instrument (Surucu and Maslakci, 2020). According to Maree (2007), internal and external validity refer to the two types of validity. A high degree of internal validity indicates that variables other than the treatment where adequately controlled, and therefore that the treatment alone resulted in a change in the dependent variable, while a high degree in the external validity indicates that the findings made based on the sample can be generalised to the entire population (Maree, 2007). Furthermore, quantitative and qualitative approaches were used in order to triangulate the findings of the study, so as to ensure the validity of its findings.

1.9.1.2. Reliability

Reliability determines whether the measuring instrument contains any errors. A reliable measuring instrument ought to produce similar results when used in the same sample at different times (Surucu and Maslakci, 2020). In this study, the reliability coefficient of the test was estimated using the Kuder-Richardson formula 20 (KR-20), which determines whether all the test questions measure conceptual understanding as they are supposed to (Njoroge et al., 2014).

1.9.2. Qualitative approach

Qualitative data gathering and analysis methods in this study were used to determine the perceptions of Grade 10 learners on their learning of chemical change under an inquiry-based approach and traditional methods classroom environments.

To answer the second research question, focus group interviews were conducted just after the posttest. According to Cope (2014), it is important for a qualitative researcher to ensure that credibility and trustworthiness are always enhanced during the research process. In qualitative research, credibility refers to the truth in the collected data as obtained from the participants, as well as to truth in their interpretation and presentation (Cope, 2014). Trustworthiness refers to the confidence in the qualitative process overall, including data gathering, data analysis, and interpretation (Golafshani, 2003). In this study, triangulation was used to enhance the credibility and trustworthiness of the study (Cope, 2014). According to Golafshani (2003), triangulation refers to combining different methods for gathering or analysing data to strengthen a research process. Furthermore, triangulation also decreases the effect of the researcher's bias in a given study (Golafshani, 2003). Cope (2014) proposed other methods that a qualitative researcher might utilise or follow in order to enhance the credibility and trustworthiness of a study, which include avoiding bias, having a journal where reflections are written, and also having an audit trail, where all the research documents, including interview transcripts, reflexive journals, and notes are kept, in order to be accessed by other researchers and to understand any assumptions and decisions.

1.10. ETHICAL CONSIDERATION

According to Kaiser (2019), researchers must have understanding of research ethics in the research process, and ensure that they adhere to all the ethical policies related to their study, so as to produce a scientifically credible research. Kaiser (2019) further states that there are principles that govern and protect the use of human participants in a research study. It is the responsibility of the researcher to ensure that the rights of the participants are always considered and respected at every stage of the research process (Nayak and Singh, 2015). Furthermore, the researcher must ensure that participation in the study is voluntary, that there is no physical harm to the participants, that participants can withdraw their participation at any stage of the study without any repercussion, and that the researcher ought to ensure the confidentiality of personal information of participants (Nayak and Singh, 2015). Kaiser (2021) adds that researchers ought to provide participants with information on how and for how long will their information be used and stored.

In order to ensure that the study meets the required ethical standard, the researcher first applied for ethical clearance from the University of South Africa's (UNISA) College of Education's Ethics Committee prior the data gathering process. After obtaining ethical clearance, the researcher requested permission to conduct the research in the selected schools from the Ehlanzeni District. The permission was granted by the District, followed by the school principals, SGB chairpersons, teachers, parents, and the learners concerned. Moreover, Consent was informed, where learners were briefed about the study and its aims and objectives, and it was indicated to them that they are free to withdraw their participation in any stage of the research study (Bidi, 2018). Learners who wished not to be part of the study were allowed to participate in class activities, since the topic of chemical change is examined in the end-of-year examinations as part of their syllabus, but their scripts were not marked. Furthermore, the learners' scripts were coded, where instead of writing their names on the scripts, learners used codes like L1 for the first learner, L2 for the second and so forth (Blyth, 2010).

1.11. DEFINITION OF KEY CONCEPTS

Conceptual understanding: "…a power which relates the information contained in the understood concept with the schemes owned previously and makes one able to re-express a concept, classify objects based on certain characteristics, give examples and non-examples of a concept, present a concept in various forms of mathematical representatives…" (Sari and Haji, 2022:02).

Chemical change: One of the six main knowledge areas that makes the Physical Sciences as a subject. Chemical change in Grade 10 is made up of the following topics: physical and chemical change, representing chemical change, reactions in aqueous solutions, and stoichiometry (DBE, 2011).

Inquiry-based teaching: A teaching and learning approach that is learner-centred, where learners explore, question, discover, and conduct experiments in order to develop deeper understanding of a topic of interest (Wilson, 2020).

Physical Sciences: A school subject that uses scientific inquiry, scientific theories and laws, as well as the application of scientific models to provide explanation and evidence of events occurring in the physical environment (DBE, 2011).

1.12. DELIMITATIONS OF THE STUDY

Due to financial and time constraints, the study only involved Grade 10 Physical Science learners from four high schools found in Mgwenya and Sikhulile Circuits under the Ehlanzeni School District. The focus of the study on Grade 10 Physical Science learners was informed by the fact that Grade 10 is regarded as an important grade in South African education, since it accommodates learners who are transitioning from the senior phase into the further education and training phase (FET) where they then specialise in the different fields such as the sciences. Schools around the Mgwenya and Sikhulile circuits were also selected based on their proximity to one another, and that they are situated in township and semi-township areas, which were identified as areas with a high percentage of underperforming schools in South Africa.

1.13. BREAKDOWN OF CHAPTERS

The study was organised in the following way:

CHAPTER 1: Introduction and background

The chapter provides a detailed introduction and background of the study as well as the study rationale, aim and objectives, research questions, and hypothesis. Moreover, it also outlines the methodology pursued to answer the research questions and fulfill the study aim and objectives. The methods followed to ensure the reliability and validity of the study were also briefly discussed. The chapter also addressed the limitations of the study, ethical considerations, and key terms used.

CHAPTER 2: Literature review

The chapter focused on the theoretical framework of the study as well as the review of literature related to the key concepts of the topic, which comprise of inquiry as a teaching approach in science, learners' conceptual understanding, and chemical change.

CHAPTER 3: Methodology

The chapter focused on the methodology of the study were the research approach, research design, research area, data collection instruments, population and sampling, data analysis, as well as the reliability and validity, which were discussed in detail to provide a detailed pathway followed to answer the research questions and fulfill the aim and objectives of the study.

CHAPTER 4: Data analysis, interpretation, and discussion

The chapter provides detailed quantitative and qualitative data analysis, interpretation and discussion of the data.

CHAPTER 5: Summary, conclusion and recommendations

The chapter focuses on providing summary of the entire study, summary with regards to the findings of the study, conclusion, and recommendations to the various stakeholders in education.

1.14. CONCLUSION

The introduction and background of the study, the rationale of the study, research questions, the null and alternative hypothesis, aim and objectives, methodology, and the study delimitations were outlined and briefly discussed in this chapter. The methodology and design outlined the research design and approach, population and sampling, research area, data gathering and analysis methods followed to answer the research questions of the study, and to satisfy the aim of the study, which was to determine the effects of an inquiry-based approach on Grade 10 learners' conceptual understanding of chemical change topic in Physical Sciences, with the view to improve their performance. Furthermore, the chapter briefly discussed the strategies taken to ensure the reliability of the data gathering instruments and the validity of the study.

CHAPTER 2

LITERATURE REVIEW

2.1. INTRODUCTION

A literature review is presented in this chapter that serves to discuss the theoretical framework that inspired the study, indicate the possible gap in studies conducted before, locate and position the study in a relevant body of knowledge, and highlight the potential implications of the study (Nayak and Singh, 2015). This was done by discussing the major theories that support the constructivist theory, and by reviewing studies about inquiry and key aspects of inquiry, such as types of inquiry, models of inquiry, benefits of inquiry, and disadvantages. Furthermore, studies based on conceptual understanding were reviewed, where the definitions of conceptual understanding, ways of achieving conceptual understanding, and the effects of inquiry-based approaches on conceptual understanding were discussed. Chemical change as one of the themes of the study was also explained and discussed. Moreover, reasons for the focus on chemical change were provided, as well as a further discussion of literature on the effect of inquiry on chemical change topic.

2.2. THEORETICAL FRAMEWORK

The theoretical framework of a study provides the foundation and explanation of the theories on which a research study is based (Crawford, 2020). This research work is based on the **constructivist theory of learning** as explained by John Dewey's progressive education and social learning theory (Ultanir, 2012). Constructivism can generally be described as a theory that holds that learners are able to build their own knowledge, either individually or in a group (Hein, 1991). Hein (1991) further elaborates that knowledge is built through learning, and learning must be about the learner, not the content to be taught. Hein adds that knowledge is better understood as something that one constructs during the learning process, rather than as something 'out there' that needs to be discovered. Ultanir (2012) posits that in a constructivist-orientated classroom, lessons are designed in such a way that they encourage the use of prior knowledge to construct real understanding. In other words, learners' prior knowledge play a vital role in the learners' learning process, since it provides the foundation on which new knowledge can be built (Ultanir, 2012).

John Dewey (1859-1952) is regarded as one of the most influential educational philosophers and constructivists of his time, and has influenced many educational reforms in the 21st century (Williams, 2017). According to the Dewey's social learning theory, as cited in Williams (2017), learning can only take place in an environment where learners are able to socialise with their peers, and therefore, lessons in class must be designed in such a way that they promote learners' interaction, and the school itself must be regarded as a social institution. In a classroom inspired by the Dewey's progressive education theory, learners are viewed as unique individuals, who spend time constructing their own knowledge by engaging in hands-on activities and solving problems with little interference from the teacher (Williams, 2017). Furthermore, in a progressive education-inspired classroom, the process of learning begins with learners' prior knowledge, which must be always taken into account when new knowledge is about to be introduced, such that the 'new' knowledge can build on what they already know (Hein, 1991).The progressive education-inspired classroom as described by Williams (2017) above, stands in contrast to what Dewey (1938) called the "traditional" classroom, where rote learning takes place, and the teacher is viewed as more knowledgeable, conferring knowledge on their learners (Ultanir, 2012).

The Dewey's constructivist theory is preferred for this study since the ideal progressive education-inspired classroom described by Ultanir (2012) and Williams (2017) above contains some similar features as that of an inquiry-orientated Physical Sciences classroom, which include features such as physical and mind activities, learner-centredness, individual and group activities, and the recognition of prior knowledge (Gathage et al., 2021). According to Wilson (2020), inquiry-based teaching and learning (IBTL) is a teaching approach that is learner-centred, where learners explore, question, discover, and conduct experiments in order to develop a deeper understanding of a given topic of interest during the learning process. Gyamphoh et al. (2020) state that in an IBTL classroom, learners are exposed to activities that promotes critical thinking, and develop problem-solving skills that will not only be useful in class, but also in solving real life problems. Problem-solving skills are some of the key skills associated with science learning and learners in possession of such skills have a strong conceptual understanding in science concepts (Yuliati, Riantoni and Mufti, 2018). Furthermore, the IBTL approach encourages learners to think logically, systematically, and critically as a skill that is key in understanding science (Amida and Nurhamidah, 2021). The constructivist theory as stated in Dewey (1938) and cited in Hein (1991) and Williams (2017), promotes teaching and learning that is learner-centred, acknowledges prior knowledge and learners' interaction and physical and mind activities, which according to Gyamphoh et al. (2020), are all features of IBTL approach, and are important in science learning. It is for that reason that the constructivist theory was chosen in this study.

2.3. INQUIRY AS A TEACHING APROACH IN SCIENCE

2.3.1. What is inquiry?

Different researchers have provided various definitions of 'inquiry', mostly based on the aims and objectives of their studies (Coileain, 2020; Penn et al., 2021; Teig, Scherer, and Nilsen, 2018). Wilson (2020) defines inquiry as a teaching and learning approach that is learner-centred, where learners explore, questions, discover, and conduct experiments in order to develop deeper understanding of a topic of interest. Meanwhile, Penn et al. (2021) view inquiry as a teaching and learning approach where learners play an active role in their learning, and are able to improve their understanding of core concepts and learning strategies by tackling problems that challenge their thinking, which allows them to gather evidence that subsequently enables them to understand the various aspects of the world around them. Moreover, Kazeni and Mkhwanazi (2021) describe inquiry as a teaching method where learners learn how to investigate, build knowledge, and understand the world around them, and in so doing, developing key scientific skills normally used by scientists. These scientific skills comprise questioning, data gathering, evidence review, and drawing conclusions based on the gathered evidence (Kazeni and Mkhwanazi, 2021). Of all these definitions of inquiry, that by the America's 1996 National Sciences Education Standards (NSES) is regarded as providing a fundamental definition of inquiry, especially in the research community, where most other definitions of this concept are derived from it (Jerrim, Oliver, and Sims, 2020). According to the NSES:

> Inquiry is 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, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations (National Research Council (NRC), 2000: 23).

2.3.1.1 Role of the learners in an inquiry-based teaching and learning environment

Despite the differences in the wording of the definitions of inquiry provided at a glance, one can deduce that inquiry focuses more on the learner activities, since all definitions provide the activities learners are expected to engage in during inquiry-based learning. This contention is in line with Jerrim, Oliver and Sims (2020), who claim that inquiry is aimed at providing learners with knowledge through engaging in activities normally carried out by scientists instead of receiving knowledge directly from teachers. Moreover, Coileain (2020) adds that science learning involves active participation in the learning process. In an inquiry-orientated Science classroom, learners play an active role in their learning, where they conduct investigations, perform experiments, ask questions, and make observations to solve problems, and in so doing, improve their critical thinking skills and their understanding of science concepts (Gyamphoh et al., 2020). Susilawati et al. (2020) echoes the statement by Gyamphoh et al. (2020) as they highlight that the inquiry-orientated science classroom ought to emphasise learner-centeredness, where learners learn and gathers knowledge independently, and they use their thoughts and experiences to seek out answers to problems in the classroom, as well as to solve problems they come across in their daily lives. In summary, the features of inquiry as identified by the NSES are made up of the learners' activities in an inquiry-based classroom environment. Such learner activities logically sum up the activities as deliberated upon above. The NSES learner activities include (NRC, 2000: 29):

- engagement in scientifically based questions;
- providing evidence to respond to questions raised;
- using evidence gathered to formulate explanations;
- connect formulated explanations to scientific knowledge; and
- present and support the explanations.

During such activities, learners are actively involved in the learning process, and show a high level of motivation and understanding of the concepts, and subsequently develop the necessary skills to engage problems related to the topic of interest (Wilson, 2020).

The learner activities as stated by the NSES will be adopted in this study as they summarise those provided by the reviewed studies and, because they are frequently cited (Jerrim et al., 2020).

2.3.1.2 Role of the teacher in an inquiry-based teaching and learning environment

The discussed definitions of inquiry in the reviewed literature provide roles of teachers in inquiry-based learning that are slightly different from the traditional roles that teachers normally play in classrooms. The definitions focus more on the role of learners rather than that of teachers in the classroom. This is due to the fact that inquiry-based learning is one of the modern science teaching methods that teachers need to embrace so as to do away with rote traditional teaching methods (Singh and Kaushik, 2020). Wilson (2020) criticises traditional teaching methods as she states that these focus more on what and how the teacher conducts his or her lessons, with minimal consideration of the learner. In support of the inquiry-based approach, Fielding (2021) argues that inquiry is aimed at changing the narrative that learning takes place when the teacher (regarded as more knowledgeable) transmits knowledge to the learners (regarded as less knowledgeable), to one where the teacher becomes a facilitator that challenges learners to think, analyse and conduct experiments in order to expand their knowledge related to a concept of interest. The teacher’s role changes to that of a facilitator, where a facilitator’s goal is to help learners construct their knowledge, such that they end up thinking like scientists

(Fielding, 2021). Teachers, as facilitators, must constantly provide scaffolding, and motivate the learners during the inquiry lesson, so as to ensure that the learners finish their tasks and do not lose interest in the process (Quintaneg-Abaniel, 2021). Fielding (2021) further elaborates that teacher facilitation in the science classroom also involves encouraging group discussion among the learners, while at once maintaining neutral and limited assistance in order to challenge their thinking skills. The teacher's roles as stated above raises the question as to how much a teacher as a facilitator ought to be involved in the learning process. According to Coileain (2020), the involvement of the teacher in a science classroom will depend on the type of inquiry a teacher employ in a lesson.

2.3.2. The different types of inquiry

Variation in science lessons means that different inquiry types need to be employed based on the needs of every lesson (Coileain, 2020). Jerrim et al (2020) put forward that there are two facets on which inquiry can be based, and these include the different classroom activities that learners can partake in, and the amount of teacher involvement in the lesson. There are four common types of inquiry that teachers can choose from based on their lesson's aims and objectives (Banchi and Bell, 2008; Coileain, 2020, and Mkandla, 2021). The inquiry forms are arranged such that the lowest inquiry level represents high teacher involvement, while the higher inquiry level represents the lowest level of teacher involvement, as Coileain (2020) illustrates below:

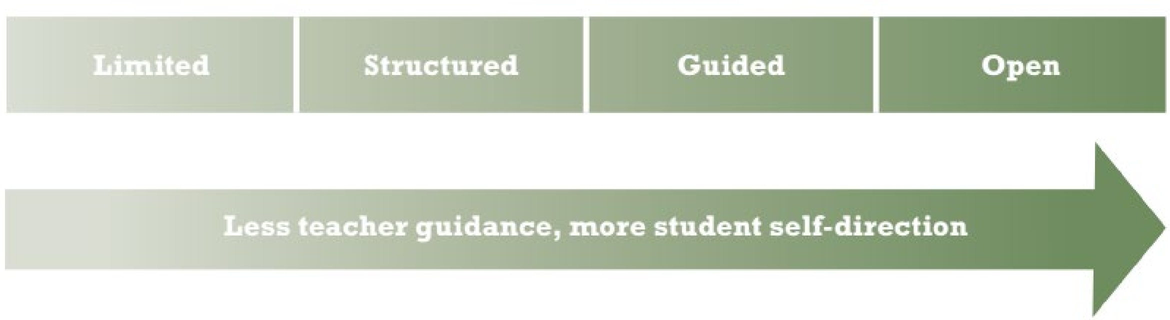


Figure 2.1: types of inquiry and teacher involvement (Coileain, 2020: 42)

Figure 1 illustrates that the higher inquiry form shows a low level of teacher involvement, while displaying a high level of learner activeness. This arrangement of inquiry set out in levels show that in the first two inquiry levels, the teacher remains dominant, while the learners' role in their learning remains limited (Coileain, 2020). The different forms of inquiry are discussed below.

2.3.2.1. Confirmation inquiry

This type of inquiry is the most basic, which is best used by the teacher to reinforce a topic that was previously taught, so as to expose learners to the various investigation skills, as well as to introduce the inquiry approach to beginners (Banchi and Bell, 2008). Mkandla (2021) describes this form of inquiry as logically positivist, since it facilitates the learning process through demonstration, where the teacher provides most of the information to the learners. Furthermore, Jerrim et al. (2020) criticise confirmation inquiry for not being inquiry enough or not involving enough inquiry activities, as learners are provided with the research questions, and the objectives and even the research outcomes are known. Criticism of this form of inquiry is mostly based on the amount of teacher involvement and learner activity during the learning process. According to Coileain (2020), in confirmation inquiry, the teacher generates the research question/s, and provides a pathway for the investigation process, as well as the answer itself, which the learners are required to confirm. In support of Coileain (2020)'s outline of the confirmation inquiry approach, Mkandla (2021) states that, in this form of inquiry, the teacher formulates the hypothesis for learners, prepares and sets the investigation equipment, and subsequently generates the conclusion. The reviewed literature describes confirmation inquiry as a form of inquiry where the teacher is much more involved in the learning process, leaving learners with less challenging activities to carry out, of which these aspects, as Jerrim et al. (2020) argues, are in contradiction with the features of inquiry. On a positive note, Mkandla (2021) insists that confirmation inquiry is still relevant and better than rote traditional teaching methods.

2.3.2.2. Structured inquiry

Confirmation and structured inquiry are the lowest levels of inquiry that a teacher can apply in the classroom (Coileain, 2020). They are labelled the lowest levels of inquiry due to the expanded role played by the teacher in the learning process (Banchi and bell, 2008; Coileain, 2020 and Mkandla, 2021). Even though in both types of inquiry, the teacher provides scaffolding during the learning process, in structured inquiry, the teacher still provides the research questions and sets up the equipment for the investigation, but the learners have to come up with their own explanation of the results, using data they have gathered themselves (Banchi and Bell, 2008 and, Mkandla, 2021). The trend that is observed is that teacher's responsibilities decreases while the learner's increases from confirmation inquiry to structured inquiry. According to Mkandla (2021), structured inquiry constitutes a form of inquiry by the teacher that teaches learners the basic scientific skills such as investigation skills and data gathering skills, so these can be utilised to deal with complicated investigations when they are engaging in higher forms of inquiry.

2.3.2.3. Guided inquiry

According to Quitaneg-Abaniel (2021), in guided inquiry, the teacher provide the research questions, at which point the learners engage in investigations in order to gather enough evidence on which they can base their conclusions. In agreement with Quitaneg-Abaniel (2021), Banchi and Bell (2008) states that, in this form of inquiry, the teacher only provides the research question/s, while learners have the responsibility to set up the investigation equipment, conduct the investigation, and provide conclusions based on the outcome of their investigation. A further decline in the role of the teacher and the rise in the responsibilities of the learners is evident in this model. In contrast with structured inquiry, Banchi and Bell (2008), contend that in guided inquiry, the learners are more involved in the learning process, where they learn scientific skills, such as the skill to set up experiment apparatus, and to conduct experiments. Moreover, Coileain (2020) adds that the teacher's role is reduced further in this form of inquiry. Guided inquiry is aimed at guiding learners during the inquiry process, and channeling learners towards evidence-based learning (Garzon and Casinillo, 2021). Jerrim et al. (2020) argues that, even though there might be useful benefits associated with this form of inquiry, such as preventing the possibility of overwhelming the memory capacity of learners as a result of engaging in high levels of inquiry such as open inquiry by providing guidance during the learning process, there are debates as to whether guided inquiry still carries the fundamental objectives of the inquiry approach. Jerrim et al. (2020) base their argument on the fact that the fundamental principles of inquiry emphasise learners' active involvement in the learning process, where they build their own knowledge and solve 'real' scientific problems through conducting scientific investigations. The debate of guided inquiry and its authenticity as an inquiry approach leave room for more studies about guided inquiry, and its authenticity as an approach, a subject which lies outside the current scope.

2.3.2.4. Open inquiry

Open inquiry constitutes the highest form of inquiry (Banchi and Bell, 2008; Mkandla, 2021; Quitaneg-Abaniel, 2021). In open inquiry, learners take ownership of their learning by engaging fully in the scientific process, where they formulate their own research questions, setup the experiment apparatus, conduct investigations, gather evidence for their conclusions, and present their results (Banchi and Bell, 2008; Quitaneg-Abaniel, 2021). The teacher's role is reduced further in this form of inquiry. Coileain (2020) describes open inquiry as a form of inquiry that offers the least teacher assistance to learners when compared to the other forms, and this is due to its emphasis on learners' self-direction. In support of this form of inquiry, Quitaneg-Abaniel (2021) states that despite the initial resistance of learners to open inquiry, after being properly orientated, learners were able to engage productively with the content and showed a high level of understanding throughout the learning process. Furthermore, Quitaneg-Abaniel (2021), emphasises that the fact that this kind of inquiry gives more freedom to learners must not deter teachers from providing scaffolding where necessary, and teachers need to constantly providing feedback so to ensure that learners are not wandering around in class. The emphasis on providing scaffolding to learners implies that learners are likely to wonder around during open inquiry. It is for this reason that Gibb (2017), the UK's Minister of Education cautioned the Education World Forum (EWF) about the negative impact of learner-centered teaching and learning approach, where he state the following"

> Whereas allowing pupils to design their own experiments; allowing pupils to investigate and test their ideas; holding class debates about investigations; and requiring pupils to argue about science questions and a number of other 'child-centred' teaching approaches resulted in a net negative impact on science outcomes (Gibb, 2017:05).

Interestingly, Quitaneg-Abaniel (2021) posits that open inquiry, or any other form of inquiry, can yield positive results in science learning, if teachers do not neglect learners. Teachers must not wander around without purpose, but instead, they must question, facilitate, provide feedback, and motivate the learners during the learning process. Furthermore, a study by Jerrim et al. (2020) found that science learners who are guided during the inquiry process are likely to perform better in an assessment than science learners who are not. Based on the reviewed literature, the importance of teacher involvement during any form of inquiry so to ensure that learners' working memory is not overworked is clear (Jerrim et al., 2020).

Teachers are not only expected to choose the appropriate form of inquiry they can employ to meet the objectives of their lessons, but they are also expected to choose appropriate learning cycle model of inquiry, which vary according to the phases in each cycle. According to Mupira and Ramnarain (2018), inquiry phases are smaller units that are connected to breaking down the complex scientific process of inquiry to ensure maximum support of learners and to highlight the key features of scientific inquiry. The logical connection of the inquiry phases forms an inquiry cycle (Mupira and Ramnarain, 2018).

2.3.3. Teaching models of inquiry

According to Nicol, Gakuba and Habinshuti (2020), many science teachers do not implement inquiry-based strategies in their lessons, because they believe inquiry-based approaches are difficult to implement. Ong, Keok, Yingprayoon, Singh, Borhan and Tho (2020) add that science teachers still regard inquiry-based approaches as unclear, ill-defined, and indistinct. It is for this reason that Nicol et al. (2020) are of the view that the use of learning cycles in designing science lessons can simplify inquiry-based lessons and give teachers the confidence to implement or integrate inquiry based strategies in their science lessons. According to Nicol et al. (2020), there are four learning cycle models that science teachers can choose from, namely the 3E, 5E, 7E and 9E learning cycle models. The 3E learning cycle model is described as the basis of the other models that succeed it, meanwhile the 5E model is believed to be the most widely used learning cycle in science classrooms (Sam, Owusu and Anthony-Krueger, 2018). Garzon and Casinillo (2021) assert that, out of all the learning cycles used in constructivist science classrooms, the 5E inquiry-based model is the most feasible approach, as it allows learners to analyse and construct new knowledge. Furthermore, a well-executed 5E inquiry-based approach will provide the same benefits as the newly designed 7E and 9E inquiry-based approaches (Nicol., 2020). It is for these reasons that the 3E and the 5E learning cycle models were discussed in detail in the current study.

2.3.3.1. The 3E learning cycle model

Science teachers are constantly reviewing their teaching approaches, with the aim of finding teaching strategies that can enhance learners' interest in the subject (Bybee, Taylor, Gardner, Van Scotter, Powell, Westbrook and Lander, 2006). According to Nicol et al. (2020), the 3E learning cycle can be regarded as the fundamental theory of guided inquiry which was the product of the 1960' Science Curriculum Improvement Study (SCIS) by Atkin and Karplus (1962). The SCIS learning cycle model is embedded in Jean Piaget's developmental psychology, which focuses on the cognitive development of children (Bybee et al., 2006). Nicol et al. (2020) argue that Jean Piaget's developmental psychology generally implies that learners ought to be given space and resources to be able to build their own knowledge, rather than being given information. According to Bybee et al. (2006), there are three phases in the SCIS learning cycle, which include exploration, term introduction, and concept application, respectively. Even though the three phases of the 3E learning cycle model can have different wording, they are contextually similar. The three phases can also be termed exploration, concept development or explaining and, expansion or elaboration (Hadinugrahaningsih, Ridwan, Rahmawati, Allanas, Cahya and Amalia, 2021; Marek, 2008; Sam et al., 2018).

(I) Exploration

According to Bybee et al. (2006), the first phase of the 3E model, namely exploration, involves learners using the necessary tools to collect new information. In agreement with the statement by Bybee et al. (2006), Hadinugrahaningsih et al. (2021) states that in the exploration phase, learners collaboratively engage information to come up with concepts. Meanwhile, Marek (2008) emphasises the respective roles of the teacher and the learners on his description of the three phases in the 3E model. According to Marek (2008), in the exploration phase, learners work in groups to collect relevant data, answers questions (if any) in their stated activities, and assimilate the collected data, while the teacher's role includes collecting the relevant resources, such as laboratory apparatus, books, charts, etc. that learners will use when engaging with the activities, and providing guidance to ensure learners gather relevant data.

(II) Explaining

In the explaining phase, interpretation of the newly gathered information takes place by restructuring previous concepts (Bybee et al., 2006). Hadinugrahaningsih et al. (2021) reiterate the argument forwarded by Bybee et al. (2006) where they mention that in the explaining phase the learners actually provides an explanation of the concepts they have developed in the exploration phase. Nevertheless, Marek (2008) posits that in this phase, the teacher plays a leading role in guiding a written discussion, aimed at mentally and physically involving learners in the process of building a scientific concept of the topic of interest. The written discussion must use all the learners' collected data, and the collected data must be used to: create graphs, tables, or a written summary, ushering learners towards the interpretation of their gathered data; disequilibrate learners who have not done so as they search for meaning in their collected data; allow learners to make meaning of the newly developed science concepts; and give learners the relevant scientific terms that are related to the concept of interest (Marek, 2008). In agreement with Marek (2008), Sam et al. (2018) in the explaining phase, the teacher plays a leading role in the discussion about the learners' findings, meanwhile the learners are expected to explain the scientific principles associated with the concepts of interest in their findings.

(III) Elaboration

Elaboration or expansion constitutes the last phase of the 3E learning cycle model. According to Bybee et al. (2006) in the elaboration phase, learners unlock a higher cognitive level by utilising the knowledge they learned to solve problems, requiring knowledge similar to that which they've learned in class. Nicol et al. (2020) assert that learning is not only concerned with concept development and data analysis or elaboration, but stresses the application of the newly learned concepts, as well as scientific terminology and skills, to different situations and contexts. The elaboration activities that learners can engage in, as listed by Marek (2008), include conducting experiments, solving problems of similar context, or reading more about a given concept. Moreover, elaboration activities are notably similar to those introduced in the explaining phase, except that learners have developed conceptual understanding or should have developed conceptual understanding, and have the necessary scientific terminology used in defining or elaborating the concept (Marek, 2008).

Despite the successes of the 3E learning cycle model, a review of the model was inevitable, due to the challenges experienced by teachers and learners, which include: teachers forgetting the names of the phases of the model, inability of learners to achieve conceptual understanding, and the need to promote the learning cycle into a proper teaching approach (Nicol et al., 2020). That is when the 5E learning cycle was developed.

2.3.3.2. The 5E learning cycle model

The 5E learning cycle is described by Bybee et al. (2006), Nicol et al. (2020), and Sam et al. (2018) as the most dominant, and most-cited learning cycle model, and is made up of five phases. These phases, according to Nicol et al. (2020) and Ong et al. (2020), are an extension of the phases in the 3E model, with the addition of the engagement phase at the beginning and the evaluation phase at the end. The five phases are respectively named: engagement, exploration, explanation, elaboration, and evaluation (Bybee et al., 2006; Mamombe et al., 2020; Marek, 2008; Mupira and Ramnarain, 2018; Nicol et al., 2020; Ong et al., 2021; Ong et al., 2020; Sam et al., 2018).

(I) Engagement

The first phase of the 5E learning cycle model, which is engagement, is characterised by engaging learners in the topic of the day, where they participate in activities that requires them to expose their prior knowledge and misconceptions they have regarding the topic of interest (Bybee et al., 2006; Nicol et al., 2020; Sam et al., 2018). Mupira and Ramnarain (2018) state that it is the teacher’s responsibility to generate ways of stimulating interest in the learners and activate their prior knowledge. Furthermore, Mupira and Ramnarain (2018) state that in the engagement phase, learners or the teacher formulate the investigative question that should drive the lesson, and then learners are supposed to predict the outcome of the investigation. Nicol et al. (2020) advises that the teacher ought to delay giving the learners the investigative question or topic in favour of activities such as watching short videos, observing a demonstration, listening to a story related to the topic, or an informal discussion so to stimulate their interest and activate their prior knowledge.

(II) Exploration

The next phase is the exploration phase. The exploration phase develops from the engagement phase, where learners now have to explore the many ideas they just developed during the engagement phase (Bybee et al., 2006). This is done by engaging learners in interactive and minds-on teacher-initiated activities, which expose learners to genuine investigations into science concepts related to the topic (Mupira and Ramnarain, 2018; Sam et al., 2018). The objective of such activities is to compel learners to develop conceptual understanding in scientific concepts and science principles, especially those related to the topic of the day (Sam et al., 2018). In addition to the development of conceptual understanding, Nicol et al. (2020) posit that this learner-centred phase is also aimed at developing learners' critical thinking and processing skills. In a nutshell, learners are now given probing activities that provide them with experiences to develop skills and concepts (Mamombe et al., 2020). Where learners have many activities to engage in during the exploration phase, it becomes a question as to what the teacher's role may be during the exploration phase. According to Warner and Myers (2017), in the exploration phase, the teacher observes and guides the learners in order to provide them with the necessary scaffolding. Moreover, even though learners are expected to participate in group work, the teacher must encourage learners to work as independent as possible (Ong et al., 2020).

(III) Explaining

The third phase is explaining. According to Bybee et al. (2006) and Ong et al. (2020), the explaining phase draws learners' attention to specific aspects of the previous phases, which they are then expected to explain. Learners might experience some difficulty with providing clear explanation, and the teacher must use the necessary expertise and approaches to fine-tune learners' explanations (Bybee et al., 2006). Nicol et al. (2020) describe the explaining phase as a teacher-guided phase, according to which learners are expected to apply their minds in providing explanation for what they have observed or discovered in the previous activities they encountered. Their explanation will demonstrate to the teacher whether they have understood the concepts or not (Ong et al., 2020). The teacher then, after observing and guiding, correct the noted misconceptions, explains the concepts, and introduces scientific terms (Mamombe et al, 2020). Nicol et al. (2020) add that, after the learners have provided their explanations, the teacher can then use different learning aids, such as power-point presentation, educational videos, and performing a roleplay, to introduce scientific theories and principles associated with the observations made and explained by the learners.

(IV) Elaborate

According to Bybee et al. (2006), the elaborate phase is characterised by the involvement of learners in activities that go beyond the concepts of interest, where they are now required to apply the acquired concepts, skills, and experiences to similar situations. In support of Bybee et al. (2006), Warner and Myers (2017) indicate that, during the elaboration phase, learners make connections between new concepts, discoveries, principles, and real-world experiences, and apply these to new situations. They can do so by engaging in learner-centred activities, such as quizzes and other minds-on activities, which can also be used to assess the learners in the evaluation phase (Nicol et al., 2020). In addition, learners can be required to use the learned skills to solve problems that will confirm their understanding of those skills (Mupira and Ramnarain, 2018). Ong et al. (2020) assert that this phase is important for the development of learners' conceptual understanding of science concepts and skills obtained in the previous phases. Moreover, Warner and Myers (2017) posit that, unlike the traditional memorisation method of learning, the application of concepts and knowledge allow learners to gain understanding of the scientific concepts they are learning.

(V) Evaluation

Evaluation is the 5th and the last phase of the 5E inquiry-based model. Evaluation provides learners with the opportunity to display their understanding of the learned concepts and their ability to apply the newly obtained scientific skills (Bybee et al., 2006). Mupira and Ramnarain (2018) add that in the evaluation phase, the teacher assesses the learners based on the objectives of the initial topic. Furthermore, the teacher conducts assessments in order to determine whether the learners managed to achieve the expected learning standards and goals. Sam et al. (2018) highlight that it is not only teachers that can assess learners, but also the learners can assess one another. The teacher can informally assess the learners through various activities, or the learners can informally assess one another in the classroom through activities such as presentations and quizzes (Nicol et al., 2020). Formal assessments in the form of examinations can be conducted by the teacher at the end of the year or term, in order to assess whether the learners managed to achieve competency in the concepts of interest (Nicol et al., 2020). Nicol et al. (2020) further caution that it must be noted that the evaluation phase is a phase unto itself, or can be implemented during other phases of the learning cycle.

The popularity of the 5E inquiry-based approach in the research community and its effectiveness in encouraging active learning, which is the cornerstone of science education (Nicol et al., 2020), positions this approach as a reputable science learning approach.

2.3.3.3. Why learning cycles?

Sam et al. (2018) describe the learning cycles as inquiry-oriented teaching strategies that can be traced back to the constructivist theory of learning, which encourages learners to be at the forefront of the learning process by engaging in minds-on and hands-on activities. Well-planned learning cycles have the potential to enhance the skills that are key to science learning, such as problem-solving and critical thinking skills (Nicol et al., 2020). The knowledge that is obtained through the use of learning cycles is likely to be permanently retained, due to the fact that, in learning cycles, knowledge is presented logically and structured (Nicol et al., 2020). Through constructive engagement, learners exposed to learning cycles show a high level of interest in their learning, have a positive attitude towards the knowledge acquisition process, and have meaningful ideas (Marek, 2008). In summary, learners in a learning cycle-based science classroom environment have enhanced scientific reasoning, meaningful scientific ideas, and show a high level of classroom involvement (Marek, 2008). For teachers, Nicol et al. (2020) argue that the learning cycle approach acts as a support mechanism for teachers, with simple and structured phases of inquiry for easy lesson planning and preparation.

2.3.4. The adoption of IBTL in science curriculums around the globe

Successful science learning must be executed using teaching and learning methods such as the inquiry-based learning cycle approach, which will develop critical thinking skills, promote successful collaborative engagement to facilitate informed decision-making among learners, and enhance problem-solving skills (Sutaini et al., 2021). According to Amida and Nurhamidah (2021) ,inquiry-based approaches encourage active participation and decision-making by learners during lessons in inquiry-oriented science classrooms. Furthermore, the NSES posits that the goals of every science lesson must be to teach learners scientific concepts and principles, provide learners with the same skills used by scientists in their scientific processes, and to ensure that learners have a better understanding of the nature of science (NRC, 2000).

Many countries have relied on the 1995s NSES standards to change or amend their science curricula to reflect inquiry-oriented learning (Jerrim et al., 2020). Since then, a large number of countries have advocated for the use of inquiry-based approaches in their schools' science curricula (Coileain, 2020; Jerrim et al., 2020; Mupira and Ramnarain, 2018; Mkandla, 2021; Ong et al, 2020; Ong, Govindasamy, Singh, Ibrahim, Wahab, Borhan, and Tho, 2021; Penn et al., 2021; Quitaneg-Abaniel, 2021; Sam et al., 2020; Tecson, Salic-Hairulla, and Solerai, 2021). The inclusion of inquiry-based learning in science curricula across the globe is influenced by the narrative that science learning ought to develop critical thinking and reasoning skills by engaging learners in thought-provoking activities integral to the scientific approach (Teig et al., 2018). For example, the Malaysian primary school curriculum emphasises the implementation of inquiry-based learning so as to enhance learners' higher-order thinking skills (HOTS) and other skills required to produce competitive learners in the 21st century (Ong et al., 2020). Inquiry elements are also noted in the Philippine's k-12 (kindergarten to Grade 12) curriculum. According to Tecson et al. (2021), one of the aims of the k-12 curriculum in the Philippines is to provide science learners with the skills that will be used beyond the classroom to produce citizens that will positively engage environmental, health, and social issues affecting the society. Moreover, the 2003 science curriculum for Irish learners in the Junior Certificate band, as published by the Education Department, highlight the importance of learners' involvement in conducting scientific experiments to understand the nature of science (Coileain, 2020). Coileain (2020), further emphasises the Irish government's commitment to providing inquiry-oriented education, by decreasing the amount of work to be covered in the science curriculum to give teachers more time to engage learners in inquiry-based learning.

The adoption of inquiry-based approaches in school curricula is a global one, including African countries. According to Sam et al. (2018), the biology senior high schools' curricula in Ghana advocates for the implementation of inquiry-based approaches for teaching and learning. Sam et al. (2018), argue that the insistence on the implementation of inquiry-based approach is due to the fact that such approaches are believed to develop and promote a mastery of skills that are crucial for survival in the 21st century.

The call for IBTL in science classrooms is also evident in the South African sciences CAPS curriculum (Kazeni and Mkhwanazi, 2021; Kibirige and Maponya, 2021; Mkandla, 2021; Mupira and Ramnarain, 2018; Penn et al., 2021; Sondlo and Ramnarain, 2021). The Grade 10–12 Physical Sciences CAPS document emphasises the use of inquiry-orientated teaching strategies in order to stimulate interest, and provide learners with the skills they need to solve real life problems (Penn et al., 2021). According to the Physical Sciences CAPS curriculum's Specific Aim 1, the main aim of the Physical Sciences as a school subject is to:

> …make learners aware of their environment and to equip learners with investigating skills relating to physical and chemical phenomena, for example, lightning and solubility. Examples of some of the skills that are relevant for the study of Physical Sciences are classifying, communicating, measuring, designing an investigation, drawing and evaluating conclusions, formulating models, hypothesising, identifying and controlling variables, inferring, observing and comparing, interpreting, predicting, problem-solving and reflective skills (DBE, 2011:8).

Furthermore, Sondlo and Ramnarain (2021), state that the Physical Sciences CAPS curriculum's Specific Aim 2 promotes the use of IBTL, by stressing the active participation of learners during lessons, and by encouraging discovery learning with minimal teacher activity during lessons.

It is not only the specific aims of the Physical Sciences' CAPS curriculum, but also the general aims of the South African curriculum that promote inquiry-based teaching and learning methods. One of its general aims states that teachers must ensure that learners are active participants in the learning process and take a critical approach to learning, rather than subjecting learners to rote learning (DBE, 2011). This view of the general aims shows that the government does not only encourage inquiry-based learning in scientific subjects, but in all school subjects or learning areas in South Africa, as the general aims apply to all the subjects in the South African CAPS curriculum.

2.3.4.1. The difficulty with implementing inquiry-based approaches

Even though the CAPS curriculum emphasizes the use of IBTL in science classrooms, the curriculum itself does not give teachers enough room to implement it (Sondlo and Ramnarain, 2021). Sondlo and Ramnarain (2021) argue that teachers do not have enough space to explore various teaching methods or integrate their own creative strategies into what the curriculum require since the CAPS curriculum is designed in such a way that teachers must teach exactly what the curriculum stipulates, point by point, without alteration. In echoing the sentiments of Sondlo and Ramnarain (2021), Quintaneg-Abaniel (2021) state that teachers in the Philippines are struggling to apply inquiry-based approaches in their lessons despite these being prescribed by the curriculum. Teachers in the Philippines indicate that they are unable to apply inquiry approaches, due to a lack of the necessary resources and infrastructure, time limitations, poor understanding of inquiry-based approaches, not possessing appropriate skills to deliver lessons based on lesson plans constructed from inquiry-based approaches, and a lack of a clear pathway or instructions from the syllabus. Meanwhile, regardless of the recommendations by the curriculum in Singapore, teachers still prefer other methods of teaching than the inquiry-based approaches. Their rejection of these approaches stems from the fact that they are not skilled enough to properly employ the inquiry-based approaches in their classes, and also the results-based Singaporean curriculum does not assist them in their teaching (Quintaneg-Abaniel, 2021). In the South African context, Mamombe et al. (2020), Mupira and Ramnarain (2018) and Penn et al. (2021) consider the inability of teachers to implement IBTL in their science classrooms to be due to a lack of infrastructure like laboratories, lack of teaching and learning resources, poor training or workshop of teachers when it comes to different science teaching and learning approaches, and a lack of support of Science and Technology educators. Moreover, Mkandla (2021), in his thesis about science teachers' views about implementation of IBTL in their classes, found that many teachers complained about the congested Science Annual Teaching Plan (ATP), which does not provide them enough time to integrate IBTL in their lessons. They indicated that they are expected to teach everything according to the ATP, since the summative assessments are solely based on what is indicated in the ATP (Mkandla, 2021).

The reviewed literature suggest that teachers are experiencing similar challenges that make it impossible for them to implement inquiry-oriented teaching and learning approaches in their science classrooms, resulting in them resorting to 'tried and tested' traditional teaching approaches like the lecture teaching method. Their reasons can be grouped into professional-based and system-based teaching, with the professional-based involving their skills/lack of skills, and a lack of teacher development, etc. The system-based approach involves a lack of resources, packed curriculum, silent curriculum, poor infrastructure, and lack of teacher support. Based on the findings from several studies about the positive impact of implementing IBTL in science classrooms, the emphasis of the Physical Sciences CAPS curriculum, and the global advocacy of the use of the different inquiry-based teaching approaches, it can be concluded that the advantages of IBTL in the learning process outweigh the grievances of teachers about the implementation of IBTL in their classes. Ramnarain and Hlatshwayo (2018) argue that, rather than always complaining about the curriculum and other aspects hindering their ability to implement IBTL, teachers ought to implement inquiry-based teaching according to their individual classroom situations using the resources at their disposal. I submit that further research is thus required to determine inquiry models that can be utilised in the widely varied classrooms with unique learners to improve the learning experience, as Khalaf and Zin (2018) indicate that teachers are still not confident enough to implement inquiry-based approaches, where as a result, there is a need for more studies about inquiry and possibly inquiry models that can be used in different types of classroom environments.

2.3.5. Benefits of inquiry: The positive effects of IBTL

Why do science curricula across the globe emphasises the implementation of IBTL approaches? The findings of many studies (as reviewed according to the identified themes of the current study) recently conducted on inquiry-based approaches indicate that the implementation of the various inquiry-based approaches in science classrooms had a positive effect on learning and learners' achievement in the subject (Gathage et al., 2021; Kacar, Terzi, Arikan and Kirikci, 2021; Mamombe et al., 2020; Mupira and Ramnarain, 2018; Ong, Govindsamy, Singh, Ibrahim, Wahab, Bohan and Tho, 2021; Singh and Kaushik, 2020, and Wilson, 2020). Greater emphasis will be placed on findings of studies about the effect of IBTL on learners' self-concept and mastery goals, teaching and learning of science, and science learners' achievement conducted in South Africa and elsewhere in the world.

2.3.5.1. The effect IBTL on science learners' self-concept and motivation

A quantitative study conducted by Gathage et al. (2021) in Kenya about the effect of IBTL on high school science learners' self-concept concluded that IBTL has a significant impact on science learners' self-concept. The quasi-experimental study with the Solomon's four pretest and posttest non-equivalent groups design used a sample (target population of 1600) of 160 secondary school learners from four different high schools, including two boys-only schools and two girls-only schools to gather quantitative and qualitative data from a self-concept questionnaire, with four self-concept indicators, which includes: self-image, self-esteem, self-identity, and role performance. The questionnaire produced quantitative and qualitative data, which was analysed using quantitative and qualitative data analysis methods. The quantitative data was analysed using descriptive and inferential statistics, while the qualitative data was analysed using thematic content analysis. After the analysis of the results, it was found that IBTL showed a positive impact on all but one self-concept indicator. Despite the fact that role performance seemed not to be affected by the implementation of IBTL, the findings concluded that IBTL has a positive impact on science learners' self-concept. According to Gathage et al. (2021) learners with high self-concept feel that they are in charge of their learning, they are eager to learn, and they believe nothing is too hard for them to learn. Such learners are likely to perform better in science, since they have what it takes to solve real-life problems (Gathage et al., 2021). Inquiry-based approaches do not only improve learners' self-concept, but also their mastery goals. In a quasi-experimental study conducted by Mupira and Ramnarain (2018) in South Africa on the effect of the 5E inquiry-based approach on Grade 10 Physical Sciences learners' achievement goals, it was found that learners taught using the inquiry-based approach are likely to have improved mastery goals. This means that learners taught using the inquiry-based approach will show improved knowledge of the subject, dedicate more time to their studies, develop understanding of their school work, put in extra effort in their school work, be eager to learn regardless if they make mistakes or not, and go the extra mile in their learning journey (Mupira and Ramnarain, 2018). Moreover, Mupira and Ramnarain (2018) argue that learners who have improved mastery goals will develop conceptual understanding of the concepts they are learning and therefore are likely to have improved performance in the concepts of interest.

2.3.5.2. The effect of inquiry on teaching and learning of science

Singh and Kaushik (2020) conducted a quantitative quasi-experimental study involving the pre- and posttest non-equivalent groups so as to determine whether the 5E inquiry-based method has any effect on the teaching and learning of chemistry in 120 secondary school science learners in India. The study also examined the performance of rural and urban learners in chemistry after being taught using the 5E inquiry-based approach, along with the role played by gender on the performance of learners in chemistry. The 60 learners in the experimental group were taught using the 5E inquiry-based approach while the 60 learners in the control group were subjected to the traditional-based teaching approach. Learners in both groups were given a pre-test and after the treatment they were all subjected to a posttest, and the results were analysed using statistical methods including the mean, standard deviation, and t-test. The study concluded that the 5E inquiry-based approach is more effective in chemistry teaching than the traditional-based approach. It also concluded that there is no significant difference in the performance of learners in rural and urban areas in chemistry after being taught using the IBTL approach. Furthermore, it was found that the gender of the learners does not play a significant role in their performance in chemistry. The research findings imply that IBTL is more effective than the traditional teaching approach, where IBTL is effective in learners both in rural and urban areas, and that both female and male learners benefit equally from IBTL. The findings of this study can be useful to South African science educators as Mamombe et al. (2020) indicate that learners perform poorly in science, especially in chemistry. Moreover, Mupira and Ramnarain (2018) mention that science learners in rural and township areas perform more poorly than their counterparts in urban areas. Therefore, according to Singh and Kaushik (2020), IBTL has a positive impact on the performance of learners in rural areas in chemistry.

A contextually similar study was conducted by Ong et al. (2021) regarding whether the implementation of 5E inquiry-based model in a classroom improves the performance of learners in electricity. The quasi-experimental study involving pretest and posttest non-equivalent groups was conducted with a sample size of 65 Malaysian primary school Science learners, with 32 learners constituting the control group and 33 making up the experimental group. The learners in the experimental group were taught using the 5E inquiry-based model while those in the control group were taught with the traditional-based approach, and thereafter they were all given a posttest comprising of 20 multiple choice questions, as well as other test materials. The results were quantitatively analysed using mean, analysis of variance (ANCOVA), and t-test analysis. The study concluded that IBTL is effective in improving the performance of learners in electricity, especially those learners who are underperformers in the topic. Since the study was conducted in a single school with only 65 learners, there is a need for more studies that can examine the same topic, but with a larger sample size and different study environments, so as to enhance the validity of the study and generalise the findings to a larger population. In the above studies, quantitative data were collected and analysed quantitatively. I therefore suggest that more studies on similar topics can be conducted in order to provide an in-depth analysis of the topic by using both qualitative and quantitative methods. According to Mensah-Wonkyi (2016), the use of both quantitative and qualitative methods in a study provides an in-depth analysis of the topic of interest.

2.3.5.3. The effect of IBTL on learners' academic achievement

Kacar et al. (2021) conducted a meta-analysis of IBTL and its impact on academic achievement. The study focused on determining whether there is any relationship between IBTL and learners' achievement in the subject by analysing the findings of 30 articles and theses of studies conducted in Turkey between the year 2000 and 2020 (Kacar et al., 2021). The main selection criteria for the study was that they fall within the indicated period, should be quasi-experimental studies, and must have used a statistical method to select the sample size for proper generalisation to the entire population. The findings of the meta-analysis indicate that IBTL significantly increases the academic achievement of learners at high school level, more so than any other school level (Kacar et al., 2021). The focus on learners' marks concluding that the inquiry-based method was successful might not be convincing enough that indeed IBTL improve learners' performance. I therefore propose that more studies that will focus on the exact aspects of inquiry that improve the learning process, and how those aspects can be improved in the classroom need to be conducted. Furthermore, various data collection methods need to be used in order to improve the validity and reliability of the study (Suruca and Maslakci, 2020). According to Bidi (2018), triangulation is key to ensuring that the results obtained in a given study are trusted, where using only one data gathering method (test marks) might not give in-depth information about the effect of IBTL on learners' performance.

The findings of Kacar et al. (2021) are in line with the findings of Wilson (2020) regarding her meta-analysis study of four studies based on the impact of IBTL on science learners' achievement, motivation, and their ability to retain the learned knowledge. Her selection criteria for the studies to be reviewed did not focus on their origin, but on whether the study focuses on: (I) utilising IBTL to improve learner achievement, motivation and ability to retain learned knowledge; (II) uses different inquiry-based teaching approaches, and also (III) studies conducted in IBTL conducive environment. Based on a review of these studies, Wilson (2020) concluded that the implementation of IBTL in a science classroom does increase the learners' achievement, motivation, and ability to retain learned knowledge. She further recommended that science teachers need to embrace IBTL and implement it in their science classrooms, so as to assist the learners to actively engage with their classroom activities and create a classroom that encourages learners to own their learning process, by making discoveries and solving problems individually as well as in groups.

Moreover, Fielding (2021) conducted a study to analyse inquiry-based strategies to accommodate both low- and high-performing learners in science classroom. In her thesis, she concluded that a 5E inquiry-based model does accommodate all learners in a science classroom, regardless of whether or not they are low or high achievers in the subject.

In summary, the literature reviewed show that inquiry-based approaches, especially the 5E inquiry-based model, contributes positively in the learning experience of learners irrespective of their social background, location, subject, gender, and performance level. Khalaf and Zin (2018) argue that despite the many success stories of inquiry, further studies need to be conducted for teachers to have an uncontestable understanding of the inquiry-based approaches, so that learners can fully benefit from them. I therefore put forward that further research is necessary, particularly using novel research designs and multiple data gathering methods, covering different social, economical and geographical backgrounds than the ones used in the reviewed studies, and conducted amongst larger sample sizes so that findings can be generalised to larger populations. Furthermore, it is necessary that studies focus on the effect of inquiry, that is, not only on performance, but also on the exact aspects that results in improved learner performance.

2.3.6. Critics of inquiry-based teaching and learning approaches

How much guidance must be given to learners during an inquiry-based lesson? Most criticism of inquiry-based approaches emerges from posing this question. In their study focusing on the relationship between inquiry-based approaches and learners' achievement in science examinations in England, Jerrim et al. (2020) found that there is no relationship between learners who are frequently exposed to an unguided inquiry-based science lesson, and their achievement in the subject, where only a small positive relationship between highly guided inquiry-based lessons and learners' achievement in science are found to exist. Jerrim et al. (2020) argue that learners who are taught with an unguided inquiry-based teaching approach are likely to ‘overload’ their memory, due to the complex nature of scientific investigations, and therefore distract the learning process. They further argue that teaching science under a highly guided inquiry-based learning environment will be a step away from the fundamental principles or aims of inquiry that stress discovery learning (Jerrim et al., 2020). Jerrim et al. (2020) concluded that higher levels of inquiry, such as open inquiry, often leave learners at a loss during the learning process, meanwhile low levels of inquiry like confirmation inquiry are deemed not to be true forms of inquiry, as the teacher provide the research question, and gathers and set the experiment apparatus, where learners only have to confirm the answers. Quitaneg-Abaniel (2021) attest to the conclusion by Jerrim et al. (2020) that not only learners are left wondering during an open inquiry lesson, but also many teachers experiences some difficulties, especially with driving lessons that adopted the open inquiry approach. Moreover, Khalaf and Zin (2018) argue that learners undertaking lessons in an inquiry-oriented environment ought to be eager to learn and actively engage with the content, but instead, learners were found wanting, and were confused during a laboratory exercise. The learners were left to fend for themselves, without any assistance from the teacher (Khalaf and Zin, 2018). According to Khalaf and Zin (2018), this led to a resistance amongst learners to inquiry-based approaches.

Teig, Scherer and Nilsen (2018) conducted a study focusing on determining whether there is a linear relationship between inquiry-based approaches and learners' achievement in science, by analysing Norway's 2015 trends in international Mathematics and Science study results (TIMSS). They concluded that even though a positive relationship existed between inquiry and learners' achievement, the relationship is not linear, as initially assumed, but is instead curvilinear. Furthermore, they found that too many inquiry activities can have a negative effect on learner achievement. To clarify, Teig et al. (2018) emphasised that this does not necessarily mean that teachers ought not give learners more inquiry-based activities, but that they must ensure that they are assisted during the inquiry-oriented lesson so that they do not feel overwhelmed.

2.4. LEARNERS' CONCEPTUAL UNDERSTANDING

2.4.1 What is conceptual understanding?

Conceptual understanding refers to the foundation of learning in science, where learners who understand a concept will have skills that are necessary to solve problems related to that concept and any other problem given to them (Makhrus et al., 2021). Sari and Haji (2021) note that conceptual understanding refers to the ability of learners to master the concepts they are studying, and being able to explain them in a way that they can easily be understood. Meanwhile, Asfar and Asfar (2020) posit that the mastering of concepts can only be achieved if learners fully understand them. In support of Asfar and Asfar (2020), Susilawati et al. (2020) adds that a deeper understanding of a scientific material at hand is key in developing the necessary mastery over skills. Primada, Distrik and Abdurrahman (2018) stress the importance of conceptual understanding in science learning, as science normally contains topics that are hard to understand for certain learners. Understanding a scientific concept means being able to creatively and critically think about it, and have the necessary problem-solving skills when engaging problems related to that concept and beyond (Makhrus et al., 2021). Moreover, Makhrus et al. (2021) assert that conceptual understanding can be indicated by the ability to find a connection between prior knowledge and new knowledge, and to use that connection to master scientific laws, theories, and principles. The literature contends that, as stands to reason, mastering a topic requires understanding of said topic. To measure or determine whether learners have mastered the content, Makhrus et al. (2021) and Primada et al. (2018) provide several conceptual understanding indicators that a teacher can use to show that a learner has developed conceptual understanding of a topic. Makhrus et al. (2021) state that in order to show that they understood a science topic or concept, learners must be able to: (I) interpret, (II) classify, (III) inference, (IV) compare and (V) explain the content. The conceptual understanding indicators identified by Makhrus et al. (2021) are in line with those provided by Primada et al. (2018), including:

I. The ability to **interpret**- learners must show that they can change the information they have learned from one type to another. For example, retrieve information from a diagram and write it in words, and vice versa. This indicator is key in ensuring that misconceptions are avoided, as learners who misinterpret information can easily internalise misconceptions.

II. The ability to **explain** – learners are expected to be able to fully explain why they selected a preferred answer.

III. The ability to **classify** – learners must indicate that they are able to group things or words or phrases according to the identified criteria.

IV. The ability to **compare** – finding that relationship that exists between two or more different topics or concepts is also an important skill that learners must possess if they are to show that they have developed conceptual understanding in the respective topics or concepts.

V. The ability to **exemplify/inference** – learners must be able to provide relevant examples used in the concept of interest.

VI. The ability to **conclude** – after engaging with the content, learners must be able to draw conclusions from the content.

In the current study the conceptual understanding indicators as identified by Makhrus et al. (2021) and Primada et al. (2018) will be used to indicate whether Grade 10 Physical Science learners have developed conceptual understanding regarding the topic of chemical change.

Despite the importance of conceptual understanding in learning of science, teachers have not managed to come up with teaching strategies that will accommodate and cater for the needs of every learner in class (Alonzo and Mistades 2021; Makhrus et al., 2021; Primada et al., 2018; Sari and Haji 2021; Susilawati et al., 2020). According to Sari and Haji (2020) and Susilawati et al. (2020), in reality, the kind of science classrooms found in many schools do not cater for the needs of all learners. The teaching strategies that teachers still apply in science lessons like the lecture method makes learners less interested in the content and less inclined to solve science-based problems (Primada et al., 2018). The classrooms are more teacher-centered, where learners have to listen to everything the teacher is saying, copy notes from the chalkboard, and answer questions from textbooks (Alonzo and Mistades, 2021 and Sari and Haji, 2021). Such classrooms do not awake the curiosity of learners, and their thinking skills are not developed enough to reinforce their conceptual understanding of the learned concepts (Sari and Haji, 2020). Furthermore, Primada et al. (2018) add that learners in such classrooms have a very low level of understanding of the content.

In science, learners are said to be learning when they actively participate in the process (Susilawati et al., 2020). In active learning, learners are involved in hands-on activities that are effective, cognitive, and stress the psychomotor domains of learning, such as conducting experiments (Alonzo and Mistades, 2021). Alonzo and Mistades (2021) further elaborate that hands-on activities develop learners' understanding of the concepts they are learning, and will eventually be able to apply the learned knowledge to solve problems they come across in their daily lives. Moreover, active learning is learner-centred, meaning that learners are at the front of the learning process, and are responsibly and independently engaging with the content so as to reinforce their understanding of it (Sari and Haji, 2021).The literature states that, for learners to develop their understanding of a concept, learning that is active and learner-centered is required. Active learning can be achieved by applying IBTL in science classrooms (Makhrus et al., 2021; Mamombe et al. (2020); Penn et al., 2021; Primda et al., 2018; and Susilawati et al., 2020). Susilawati et al. (2020) posit that the inquiry-orientated classroom emphasises learner-centeredness, where learners learn and gathers knowledge independently, and use their thoughts and experiences to find answers to solve problems in the classroom, as well as problems they come across in their daily lives.

2.4.2. The effect of inquiry-based approaches on learners' conceptual understanding

The studies reviewed are based on the identified themes of the current study, regarding the effect of IBTL on learners' understanding of science concepts, which shows that IBTL has a positive effect on learners' understanding (Bidi, 2018; Mamombe et al., 2020; Mensah-Wonyi and Adu (2016); Primada et al., 2018). The reviewed literature indicates that the implementation of inquiry-based approaches does not only improve learners' understanding of the content, but also their problem-solving skills, and motivation, as well as the elimination of misconceptions.

2.4.2.1. Studies conducted elsewhere

In a study conducted by Primada et al. (2018) in an Indonesian high school about the effect of Newton's Law Worksheet based on the 7E-inquiry model on Grade 10 learners' understanding of the Newton's Law and their ability to solve Newton's Law-based calculations, it was concluded that the 7E inquiry-based approach is better than the lecture teaching method. After quantitatively and qualitatively analysing the 20 multiple choice questions (MCQ) along with the questionnaire results, they concluded that the 20 learners taught using the 7E inquiry-based Newton's Law worksheet in the experimental group had a better understanding of the Newton's Law questions than did the 20 learners in the lecture group taught using the 'normal' Newton's Law worksheet in the control group. Moreover, Primada et al. (2018) add that the learners in the experimental group not only showed a better understanding of Newton's Law, but also that they had improved problem-solving skills than their counterparts in the control group. They claim the improvement in the results of the experimental group is due to the use of the 7E inquiry-based approach. Similar conclusion about learners understanding was reached in a quasi-experimental study conducted by Mensah-Wonkyi and Adu (2016) in two Ghanaian high schools regarding the effect of the inquiry-based approach on high school mathematics learners' conceptual understanding of cycle theorems. After quantitatively and qualitatively analysing the post-test and interview results respectively, they concluded that, despite the improvement in the conceptual understanding of learners in both groups, the 41 learners taught using the inquiry-based approach in the experimental group understood the cycle topic of theorems better than the 38 learners taught using the lecture method in the control group. Furthermore, Mensah-Wonkyi and Adu (2016) assert that the learners in the experimental group were more highly motivated than their counterparts in the control group during the lessons. They therefore recommended the use of inquiry-based approaches, together with other teaching strategies, to improve learners' conceptual understanding and their level of motivation during Mathematics and Science lessons.

2.4.2.2. Studies conducted in South Africa

Mamombe et al. (2020) made the same observations as Mensah-Wonkyi and Adu (2016) regarding the improvement of the learners' understanding in both the inquiry (experimental) group and the lecture (control) group, with the inquiry group showing better improvement than the lecture group. In their qualitative pretest-posttest study, conducted in two South African farm schools on the effect of the 5E inquiry-based model on Grade Four learners' understanding of the topic of the particulate nature of matter in the gaseous phase, they determined that the 5E inquiry-based model improves learners understanding of the topic better than the lecture method. After the qualitative analysis of the posttest and interviews results, they concluded that the inquiry-based approach improves learners' understanding better than did the lecture method. Furthermore, the learners in the inquiry group had fewer misconceptions than those in the lecture group (Mamombe et al., 2020). Due to the slight improvement in the understanding of the learners in the lecture group after the lesson, Mamombe et al. (2020) suggested that properly planned lessons that uses different teaching strategies can improve learners' understanding and reduce misconceptions. The deliberations by Mamombe et al. (2020) and Mensah-Wonkyi and Adu (2016) suggest that the use of different teaching strategies can have positive effect on learners' understanding, as well as in eliminating misconceptions. The findings of Mamombe et al. (2020) are supported by those made by Bidi (2018). Bidi (2018) conducted a mixed method study that focused on the use of a conceptual change teaching approach to increase learners' understanding in Grade 11 Physical Sciences chemical change topics, as well as to determine their perceptions of the topic of chemical change. Both quantitative and qualitative methods were used to gather and analyse the data from a population of all 34 Physical Science learners in a high school in one of the rural areas of Eastern Cape Province in South Africa. In the study, all the learners first wrote a pretest, then were all taught chemical change lessons using the conceptual change teaching approach as an intervention, and thereafter, they wrote a posttest, which was subsequently followed by structured group interviews, aimed at finding out the learners' perceptions of the conceptual change teaching method. Both quantitative and qualitative methods were used to gather and analyse the data. In her thesis, Bidi (2018) concluded that the conceptual change teaching approach does improve Grade 11

Physical Sciences learners' understanding of chemical change, and it also minimises learners' misconceptions in the topic.

Generally, there are fewer studies that have been recently conducted about the effect of inquiry on learners understanding, as indicated by the reviewed literature, with even fewer studies focusing on effect of inquiry on science learners' understanding. This revelation constitutes a call for concern, as Makhrus et al. (2021) highlighted the importance of learners' understanding on the development of critical scientific skills like critical thinking and problem-solving skills. Furthermore, Alonzo and Mistades (2021) indicated that only learners who have understood a concept are able to apply it in real life situations and in problem-solving situations. The literature positions learner conceptual understanding as one of the key features of science learning, and therefore more information is needed to determine whether the inquiry-based teaching approach can improve the Grade 10 science learners' understanding of the chemical change topic. The focus on Grade 10 is necessary, because none of the studies (as far as I know) conducted in South Africa focused on Grade 10 learners' understanding despite the fact that Mupira and Ramnarain (2018) describes Grade 10 as the most important grade, as it caters for learners' transition from the GET phase to the FET phase, which is the phase that prepares learners for life beyond high school.

2.5. CHEMICAL CHANGE IN SCIENCE

2.5.1. What is chemical change in Physical science?

According to the Physical Sciences Grade 10 – 12 CAPS curriculum, chemical change together with matter and materials, chemical systems, mechanics, waves, sound and light, as well as electricity and magnetism, make up the six main topics known as knowledge areas, that are part of the Physical Science Grade 10-12 content (DBE, 2011). Chemical change, matter, and material, and chemical systems are the chemistry component of the Physical Sciences syllabus, while mechanics, electricity and magnetism, as well as waves, sound and light forms the physics component (DBE, 2011). According to the Physical Science CAPS syllabus, the Grade 10 chemical change topic, itself is made up of the following subtopics:

- Physical and chemical change – made up of the following subtopics; "physical separation of matter; chemical separation of matter; conservation of mass and atoms; law of constant composition" (DBE, 2011: 11).
- Representing chemical change – made up of balanced chemical equations
- Reactions in aqueous solutions- made up of "ions in aqueous solutions; ion interaction; electrolytes; conductivity; precipitation; chemical reaction types" (DBE, 2011: 11).
- Stoichiometry – made up of the mole concept

2.5.2. Why chemical change?

South African learners generally perform poorly in Physical Sciences (Bidi, 2018; Mamombe et al., 2020; Mupira and Ramnarain; Penn et al., 2021). Mamombe et al. (2020) argues that their poor performance in Physical Sciences is as a result of their substandard performance in the chemistry part of Physical Sciences. Mamombe et al. (2020) further assert that learners' poor background and misconceptions in chemistry lead to their poor performance in the subject. Moreover, Hadinugrahaningsih et al. (2021) posits that the substandard performance in chemistry is due to the fact that the fundamental concepts of chemistry deals with chemical representations that go beyond what the eye can see, were microscopic or even submicroscopic chemical representations are studied. For example, most learners have difficulty when it comes to understanding the language that is used in chemistry experiments, such as in acid-base reactions, and end up developing misconceptions as a result of the teacher's attempt to explain the microscopic events occurring in chemical reactions (Hadinugrahaningsih et al., 2021). Bidi (2018) goes further to specify that chemical change forms the part of chemistry that challenges many learners. Meanwhile, Amida and Nurhamida (2021) point out stoichiometry as one of the most difficult subtopics in chemical change. This is because learners are expected to think critically in order for them to engage with the content in chemical change (Amida and Nurhamida, 2021). However, Kamal and Suyanta (2020) claim that the rate of reaction topic in Grade 11 is the most challenging topic in chemistry, because learners are not challenged to think critically, where their self-efficacy remains less developed. Learners who have a less-developed self-efficacy tend to be lazy, unable to understand the content studied, and they often fail to solve-problems in a satisfactory manner, and they normally do not achieve the required goals of the lesson (Kamal and Suyanta, 2020).

According to the literature, the difficulty in chemistry content is as a result of poor conceptual understanding, lack of critical thinking skills, and the chemistry jargon terms or words that are difficult to explain, and therefore lead to learners developing misconceptions. Hadinugrahaningsih et al. (2021) forward that appropriate teaching strategies need to be used in order to overcome learners' misconceptions in chemistry, which most chemistry teachers fail to implement. Meanwhile, Sutiani et al. (2021) suggest that learners in chemistry lessons be given problem-solving activities for meaningful and memorable lessons. However, Kamal and Suyanta (2020) posit that, due to the many facets of chemistry, teachers must be experts in different teaching approaches that can be able to accommodate every chemistry topic, so as to improve the learning experience in a chemistry classroom. Furthermore, Kamal and Suyanta (2020) highlight that teaching strategies used in chemistry must encourage learners' active engagement in the learning process. Inquiry-based teaching approaches are recommended for chemistry lessons (Amida and Nurhamida, 2021; Bidi, 2018; Hadinugrahaningsih et al., 2021; Kamal and Suyanta, 2020; Mamombe et al., 2020; Singh and Kaushik, 2020; Sutiani et al., 2021),

Even though several studies have been conducted to address the challenges faced by learners with regards to chemistry (Amida and Nurhamida, 2021; Bidi, 2018; Hadinugrahaningsih et al., 2021; Kamal and Suyanta, 2020; Mamombe et al., 2020; Singh and Kaushik, 2020; Sutiani et al., 2021), I am only aware of two studies that focused on improving conceptual understanding of chemistry in South Africa (Bidi, 2018 and Mamombe et al., 2020). Of those two I am aware of , none of those focused on Grade 10 learners' conceptual understanding in chemistry, despite the emphasis by Mupira and Ramnarain (2018) that Grade 10 is the most important grade in the South African school system as it prepares learners for the transition from the Senior phase of GET to the FET phase and beyond.

2.6. SUMMARY OF THE CHAPTER

The literature review presented in this chapter has discussed the relationship between the inquiry-based teaching and learning approach and the constructivist theory of learning as a theory that inspired the current study. This was done to determine any relationship between the constructivist theory and the inquiry-based teaching approach in terms of how learners build their knowledge, and learning in general. According to the constructivist theory, learners build their own knowledge individually and in groups by learning, were learning concerns the learner, not the content to be taught. In a nutshell, both constructivist theory and inquiry-based teaching approaches uphold learner-centred learning, acknowledging prior knowledge, the interaction of learners with one another in class, and the encouragement of physical and mental activities.

Different researchers discuss inquiry differently, but all the definitions agree that inquiry is a constructivist approach that is learner-centred, and encourages active learning. There are four types of inquiry, which include confirmation inquiry, structured inquiry, guided inquiry, and open inquiry. They are arranged according to the amount of teacher and learner activities, where teachers are more active than learners in confirmation and structured inquiry. This types of inquiry are labelled 'false' inquiry, as they are more teacher-centred, and learners are less active as expected in inquiry. Teachers have various learning cycles to choose from, which include the 3E, 5E, 7E, and the most recent 9E. The 5E learning cycle is described as the most effective, since many studies produced positive effects of this form of inquiry. Despite many studies conducted regarding the 5E inquiry cycle, the literature emphasises the need for more studies that focus on this form of inquiry, and of course, other forms, so as to ensure that teachers eventually find the most suitable form or approach for them, and ensure maximum benefits to learners. Furthermore, more studies are required so as to ensure that teachers eventually embrace this constructivist approach, especially in scientific subjects. As more and more positive effects of inquiry-based approach emerge, more and more science curricula around the world embrace this method of learning, including the South African Physical Sciences CAPS curriculum. The benefits associated with inquiry include higher learner performance rate, improved self-concept and motivation, improvement of science learning, and improved understanding of scientific concepts. The main criticism of inquiry-based approaches emerges from the fact that, the ‘authentic’ form of inquiry, which is open inquiry, as identified in the literature, emphasises learners taking centre stage in their learning, were they conduct experiments and investigations as do scientists. Critics believe this kind of approach does not provide enough assistance to learners, and therefore, that learners are left not knowing what to do. In this case, learners will be demotivated, and their net performance will drop.

Conceptual understanding is described as one of the most important aspects of science learning. Learners who understand a topic are likely to have the necessary skills that include critical thinking and problem-solving skills to successfully engage activities associated with that topic or are similar to the topic. Furthermore, learners who understands a given topic are able to connect prior knowledge with the newly found knowledge. So as to develop conceptual understanding of a concept or topic, learners are required to actively participate in the learning process, where they discuss in groups, search different sources, conduct investigations, and use their results to draw conclusions. Learners are presumed to have understood a topic if they are able to interpret, explain, classify, compare, inference, and conclude about the content of the topic. The literature asserts that, in reality, current science classroom environments do not encourage learners to be actively involved in their learning. The teaching strategies that Science teachers apply in their lessons does not accommodate the needs of all learners in class, and therefore many are left demotivated, lazy to engage the content, and unable to solve problems. Inquiry-based approaches have been shown to actively engage learners, and they have been proven to enhance learners’ conceptual understanding, motivate them, and improve their problem-solving skills. There are only two studies I am aware of that have been conducted in South Africa about the effect of inquiry on learners’ understanding in science, with the latest conducted in 2020.

Chemical change is one of the six main topics in the chemistry section of Physical Science in the South African CAPS curriculum. Learners generally perform poorly in this section, and their poor performance can be traced to their poor understanding of chemistry concepts, misconceptions, and their poor background in chemistry. Chemical change is described as the most difficult topic to understand in chemistry, with rates of reaction, acid-base reactions, and stoichiometry being the most challenging subtopics in chemical change. The literature posits that, despite several studies being conducted on the effects of inquiry on chemistry learning, in my knowledge only two focused on chemical change, one conducted in 2018 with Grade 11 learners, the other in 2020 with Grade Four learners. I therefore purpose that there is a need for studies that will focus on the effect of inquiry on learners' understanding of chemical change topic in Grade 10, which is described as an important grade in South African education.

2.7. CONCLUSION

In the chapter, John Dewey's constructivist theory of learning was detailed so as to provide a link between the theory and inquiry-based approach to outline the theoretical framework for the study. Moreover, the chapter also discussed the latest literature related to inquiry-based approaches, effects of inquiry-based approaches, and the chemical change topic in Physical Sciences so as to provide understanding of the research topic. The discussion of the latest literature related to the topic highlighted the gap that exists in terms of the studies conducted to date, were it was found that even though many studies have been conducted based on inquiry-based approach, only a few where conducted in South Africa. Those conducted in South Africa did not focus on the effects of inquiry on Grade 10 Physical Science learners' conceptual understating. The literature review highlighted the importance of the current study in the body of knowledge. The next chapter presents the methodology, research design, population, sampling methods, data gathering and data analysis approaches followed in order to answer the research questions.

CHAPTER 3

METHODOLOGY

3.1. INTRODUCTION

The success of a research project is dependent on the coordination between research questions, research aims and objectives, research methods, data collection, and data analysis (Bidi, 2018). This section of the study discusses the research approach, research design, selection of research participants, sampling techniques, and data collection and analysis methods employed in order to satisfy the aims and objectives of the study. The study aims to determine the effects of an inquiry-based teaching approach on Grade 10 learners' conceptual understanding of chemical change in Physical Sciences by answering the main research question:

What are the effects of the inquiry-based teaching approach on the Grade 10 Physical Science learners' conceptual understanding of chemical change and their performance in the subject in comparison with the traditional teaching approach?

The main research question led to the formulation of the following research questions:

i. What is the effect of an inquiry-based teaching approach on Grade 10 learners' conceptual understanding of chemical change concepts in Physical Sciences in comparison with the traditional teaching approach?

ii. What are the learners' perceptions on their learning of chemical change under the inquiry-based approach and the traditional based approach classroom environment?

3.2. RESEARCH APPROACH

According to De Vos, Strydom, and Fouche (2015:56), a research approach can be described as a series of processes that are followed in order to obtain scientific knowledge in the research world. The processes can be grouped into qualitative and quantitative (De Vos et al., 2015). The current research study employed both quantitative and qualitative data gathering and analysis methods, with qualitative data collection and analysis methods utilised to support the quantitative findings reached at the end of the quantitative study (Mensah-Wonkyi, 2016).

3.2.1. Quantitative approach

What is quantitative approach?

According to Marczyk, DeMatteo and Festinger (2005), a quantitative approach involves the use of statistical analysis of numerical data to make conclusions in a study. This type of research systematically analyses numerical data obtained from a representative sample to generalise the findings obtained to the entire population (Maree, 2007). A quantitative approach can be used in inferential research, where a hypothesis is tested in order to provide an explanation about a given topic or statement, instead of merely describing it (Sukamolson, 2007). Moreover, Chivanga and Monyai (2021) describe quantitative research as a research approach that uses clearly stated hypotheses in order to prove or disprove a given theory, and it focuses mostly on causal relationships.

Strength of the quantitative approach

The strength of this kind of research approach includes the use of statistical data analysis methods, which save time and resources, the scientific nature of quantitative approach makes it possible to generalise research findings from a sample to the entire population, the use of control groups increases the validity of quantitative research and, furthermore, the absence or minimal interaction between the researcher and the participants reduces the possibility of researcher biases when collecting or analysing the data (Daniel, 2016).

Quantitative aspects of the current study

In the current study, numerical data was generated from the marks that the learners obtained in the pretest and posttest. The data was then collected and analysed using quantitative methods. The quantitative data gathering and data analysis methods were employed so as to determine the effects of an inquiry-based teaching approach on Grade 10 learners' conceptual understanding of chemical change in Physical Sciences, which was the first objective of the study. The nature of the first objective of the study required the use of the quantitative approach, as this focused on determining any causal effect relationships. According to Chivanga and Monyai (2021), a quantitative approach is better suited to dealing with studies that focus on causal relationships, where one group (the treatment group) is exposed to the intervention while the other group (the control group) does not receive the treatment to test the effectiveness of the intervention. Furthermore, the quantitative approach was chosen due to its minimal interaction between the researcher and the participants, as Daniel (2016) posits that less interaction between the researcher and participants increases the validity of the study, minimising the researcher bias.

3.2.2. Qualitative approach

The study also employed qualitative data gathering and analysis methods so as to provide a deeper understanding of the findings of the quantitative approach by determining the learners' perceptions of their learning of chemical change in an inquiry-oriented classroom environment, as compared with their counterparts learning under the traditional-orientated classroom environment to address the second objective of the study.

What is qualitative approach?

According to McMillan and Schumacher (2010), a qualitative approach is a research approach that lets the researcher into the original environment of the participants, thereby allowing him to have insider perspective of their social behaviour, while studying their perceptions. Moreover, Golafshani (2003) states that the goal of a qualitative approach is to understand a given social phenomenon by engaging in methods such as interviews, observations, etc. so as to produce data in a form that can be analysed qualitatively.

Strength of the qualitative approach

The strength of this approach lies in the fact that data is collected from subjects of interest in their changing natural setting, which allows the researcher to capture the moment before and after the change occurs (Golasfshani, 2003). According to Daniel (2016), the involvement of the researcher as a research instrument in the qualitative approach makes this approach suitable for studying the feelings, thoughts, reasoning, attitudes, and etc.

of the participants in detail. Furthermore, qualitative data gathering and analysis methods can be used in conjunction with a quantitative approach to explain findings obtained quantitatively (Bidi, 2018). Interviews were used at the end of the posttest to gather qualitative data, which was then analysed qualitatively. According to Ochieng (2009), a qualitative approach is effective in cases where a particular phenomenon has to be studied in detail, or when one wants to gain an in-depth understanding of a given phenomena.

Qualitative aspects of the current study

In the current study, a detailed and deeper understanding of the learners' perceptions were studied in order to support the findings of the quantitative approach. The use of qualitative and quantitative methods in the study was also used to ensure triangulation. According to Bidi (2018), triangulation can be described as the use of different methods of gathering or analysing data in a single study. Triangulation was necessary in order to increase the validity of the study. Maree (2007) posits that triangulation according to a qualitative approach ensures trustworthiness of the collected data and interpretive validity. On the other hand, Khalid (2012) states that triangulation is key in ensuring the credibility of the study.

3.3. RESEARCH DESIGN

3.3.1.Quasi-experimental design and what it entails

The study adopted a quasi-experimental design, involving the pretest-posttest non-equivalent groups. White and Sabarwal (2014) describe quasi-experimental designs as similar to experimental designs, because they all test causal hypotheses, and they differ where quasi-experimental designs lack randomness. According to Mensah-Wonkyi and Adu (2016), quasi-experimental studies are descriptive studies that seek to estimate by how much an intervention affected a population of interest. This kind of research design is a type of experimental design that is mostly used when it is not possible to randomly assign the participants (Gribbons and Herman, 1997). It is normally not possible to separate learners in secondary school classes, since they exist as intact groups and school principals would not allow learners to be rearranged for research purposes, since such will disturb teaching and learning (Njoroge et al., 2014). Even though non-equivalent groups are used in this design, a control group that is as equivalent as possible to the experimental group in terms of characteristics was used in the current study so as to ensure that the end results were solely due to the treatment given to the experimental group (Gathage et al., 2021). Furthermore, White and Sabarwal (2014) emphasise the importance of ensuring that the characteristics of the control and experimental groups before the intervention are administered to the experimental group. These should be as similar as possible so as to guard against selection bias, which would raise the question as to whether the difference in the results is due to the intervention, or is as a result of the difference in characteristics of the groups before the intervention. The quasi-experimental design is frequently used in studies that evaluates the impact and effectiveness of a certain programme or teaching strategy, for example, it can be used by a teacher who has two teaching methods to choose from in order to determine a teaching method that will be more effective in his/her subject or topic in class (Gribbons and Herman, 1997). In the quasi-experiment pretest-posttest non-equivalent groups design, the control group and experimental group are first given a pretest in order to assess the variation in the groups (Gribbons and Herman, 1997). After the pretest, the experimental group is then given a treatment, and thereafter, both groups are subjected to a posttest (Njoroge et al., 2014). The researcher will then conclude, based on the posttest results, whether the treatment had any effect on the research, subsequently initiating a causal relationship (Njoroge et al., 2014).

3.3.2.Benefits of quasi-experimental design

The main benefits of quasi-experimental designs include the fact that they can be used in cases where it is not possible to randomly assign participants into the control and experimental groups; for example, in schools or classes, which are one unit, where it is not always possible to move learners from one class to another, as that will disturb teaching and learning (Gathage et al., 2021). Moreover, quasi-experimental designs can lead to similar conclusions as for experimental designs, provided that the pre-intervention characteristics of the control and experimental groups are as similar as possible (White and Sabarwal, 2014).

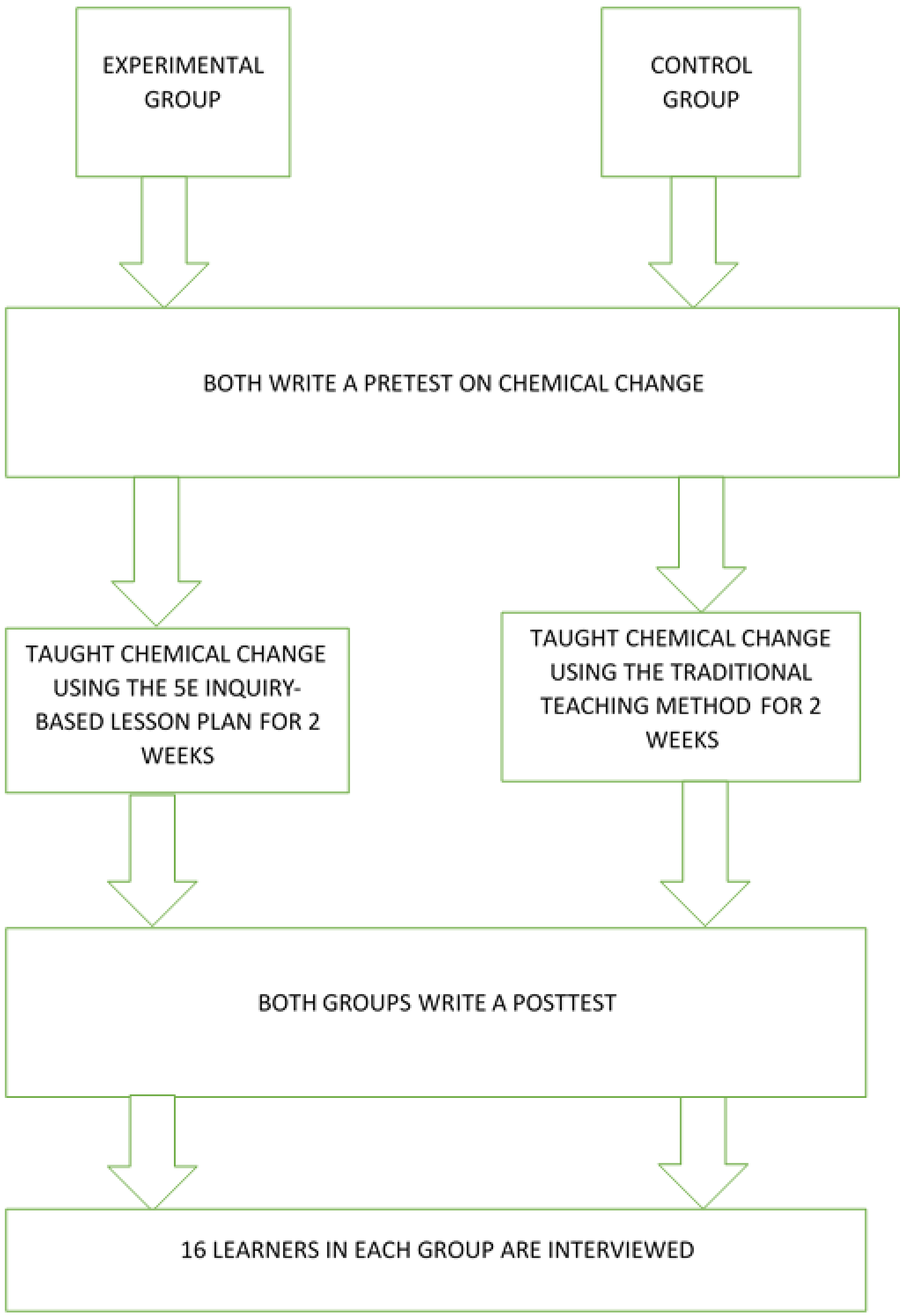
3.3.3.Disadvantages of quasi-experimental design

The main drawback of quasi-experimental designs stems from the fact that the participants in both the control and experimental groups are not randomly assigned, resulting in doubt as to whether the intervention worked, or whether the difference in the final results is due to the difference in the pre-intervention conditions of the groups. According to Gribbons and Herman (1997), certainty in quasi-experimental designs can be ensured by selecting participants that have characteristics that are closely similar as possible. In ensuring the effectiveness of the quasi-experimental design in the current study, the similarity of the characteristics of the control and experimental groups was ensured, by selecting schools that have one Physical Science class, one Physical Science teacher, semi-furnished laboratories, and selecting schools that are no-fee-schools.

3.3.4. Study activities

Figure 3.1 below outlines the activities that both the experimental and control groups embarked on for three weeks, where quantitative and qualitative data was generated from the tests and focus groups interviews, respectively. The activities of both groups include the administration of the pretest in both experimental and control groups, thereafter both groups were taught chemical change topic for two weeks. During the lessons, the learners in the experimental group engaged on hands-on and minds-on activities in the form of group discussions, observations, conducting experiments and presentation of results, all guided by the 5E-inquiry-based lesson plan. On the other hand, the control group engaged on activities were the teacher was presenting the lessons while the learners take notes, ask questions and answer a worksheet designed by the teacher based on the traditional approach. Thereafter, a posttest was administered to both groups to conclude the quantitative data gathering process. After the posttest, a qualitative data gathering process commenced where learners in both groups were interviewed to gather data that will support the quantitative findings. During the interviews, learners in both groups discussed their experiences during the lessons guided by the questions asked by the researcher. The conclusion of the interviews marked the end of the data gathering process and the commencement of the data interpretation and analysis process.

FIGURE 3.1: Illustrates a schematic diagram of the summary of the research activities



3.4. RESEARCH AREA

The study was conducted in four schools that were purposively sampled, based on having one Physical Science class and taught by one teacher, being no-fee-schools, having semi-furnished laboratories, and having about 40 learners in the science class. All four schools are situated within a radius of 15-20km from one another in the Ehlanzeni School District, under the Sikhulile and Mgwenya circuits. The schools are found around Lekazi Township and Msogwaba Trust (Semi-Township), which are within the same proximity, and are about 30km from Mbombela, the capital city of Mpumalanga Province. Mpumalanga is one of the nine provinces of South Africa. According to Mupira and Ramnarain (2018), a township in the South African context is a previously disadvantaged area that was allocated for “non-white” citizens by the apartheid government. Mupira and Ramnarain (2018) further elaborates that learners from township schools normally perform poorly in Physical Science and Mathematics, when compared to their counterparts in town schools. They ascribe the poor performance of learners in townships to poor infrastructure, overcrowded classrooms, and lack of resources, such as laboratory equipment and textbooks.

3.4.1. Research Participants

The research participants were Grade 10 Physical Science learners, in four high schools, under the Ehlanzeni District in Mgwenya and Sikhulile Circuits, which are situated to the east of Mbombela, about 30km from the capital city of Mpumalanga Province. There were 142 participants in the study, all from four intact classrooms, in four different high schools, selected from about 20 high schools in the two circuits. Table 3.1 below shows how the 142 learners were allocated in the experimental and control groups, with E representing the experimental group and C representing the control group. E1 and E2 represent the two classrooms in the two schools designated as the experimental group, while C1 and C2 represent the two classrooms in the two schools designated as the control group.

TABLE 3.1: The distribution of the study participants in both the experimental and control groups

E1	47	**C1**	41
E2	26	**C2**	28
TOTAL	73	**TOTAL**	69

There were 74 learners altogether in the experimental group, but one learner from E2 only wrote the pretest, and was not present when the posttest was written, where subsequently the learner's pretest script was removed, and his marks were not used in the study. The removal of the learner's script reduced the participants in the experimental group from 74 to seventy-three. Therefore, the number of participants in the experimental group constitute a participation rate of 98.65% of the expected number of participants, which is fairly acceptable. Meanwhile, all the learners in the control group (C1 and C2) participated in the study, since they all wrote the pretest and the posttest. Consequently, participation by all the learners in the control group is commendable, as it constitutes 100% participation of the expected number of participants.

3.5. DATA COLLECTION INSTRUMENTS

3.5.1. Pilot study

According to Dipoy and Gitlin (2011), a pilot study is one that is conducted before the actual study takes place, so as to evaluate whether the data gathering instrument meets the needs of the study, and if not, would then be edited accordingly.

The current study used pilot study to check whether the pretest and posttest questions measured the five conceptual understanding indicators (interpret, compare, explain, inference, and classify) as they were supposed to, in order to check whether the questions were appropriate and understandable to Grade 10 learners, as well as to detect any mistakes that the researcher could not pick up. The pilot study was conducted with 35 Grade 10 learners and three teachers in two schools that were within the two relevant circuits. Based on the findings of the pilot study, some questions in the test had to be redrafted, as learners struggled to answer due to the fact that they could not understand them, while two others were replaced on the advice of the teachers, as, according to them, they were not appropriate to the level of the learners. Moreover, eight of the 35 learners were asked the interview questions so as to determine whether the questions were understandable, could be answered within one hour, and to measure the perception of learners on their learning of chemical change as they were supposed to do. Informed by the findings of the pilot study on the interview questions, the researcher had to edit some questions that were not guiding them to the pre-identified themes, were not understandable, or where the language was not at their level of understanding. There were 14 interview questions initially, but the learners could not finish them in one hour so the researcher had to remove one question from the four perception indicators so as to make them two instead of three questions per indicator.

3.5.2. Pretest and posttest

The tests comprised of 10 multiple choice questions (MCQ), which were designed in consultation with textbooks, previous question papers, and the CAPS document, according to the requirements of the chemical change topic as this appears in the Grade 10 Physical Sciences curriculum document. The questions in the pretest and posttest were designed to test for conceptual understanding using conceptual understanding indicators identified by Makhrus et al. (2021), which include: interpret, compare, explain, inference, and classify. Two questions in the test were testing for each indicator, and therefore there were 10 questions in total, testing for the five indicators of conceptual understanding. The pretest was written by both the control and experimental groups. The aim of the tests was to gather quantitative data from the marks obtained by the learners in the tests so as to determine whether the inquiry-based teaching approach had any effect on the learners' conceptual understanding of chemical change. The pretest was written by learners in both the control and experimental groups before the intervention so as to assess any difference in the performance of the learners in both groups. According to Gribbons and Herman (1997), it is important to ensure that there is no variation in the performance of the learners in both groups before the intervention is administered to the experimental group. Difference in the performance prior to the intervention will lead to difficulty in determining whether the improvement in performance of the experimental group in the posttest is due to the effectiveness of the intervention, or whether the experimental group was just good from the onset (Gribbons and Herman, 1997). After the pretest, learners in both groups were taught chemical change for two weeks, with the experimental group taught with a lesson plan designed according to the 5E-inquiry model, while the learners in the control group were taught according to the traditional based teaching approach. Thereafter, learners in both groups wrote a posttest. The posttest was written so as to determine whether the 5E-inquiry model had any effect on the learners' performance and their conceptual understanding of chemical change.

3.5.3. Lesson plan intervention

The experimental group lesson plans were designed according to the 5E inquiry model, which has five inquiry phases. According to Mupira and Ramnarain (2018), inquiry phases are smaller units that are connected so as to break down the complex scientific process of inquiry to ensure maximum support of learners and to highlight the key features of scientific inquiry. The logical connection of the inquiry phases forms an inquiry cycle (Mupira and Ramnarain, 2018). According to Mamombe et al. (2020), the 5E inquiry model consists of five phases, which include Engage, Explore, Explain, Elaborate, and Evaluate. The lesson plans were designed based on the CAPS document, and the Grade 10 Physical Sciences work schedule, so that they did not divert from the allocated time in the CAPS document. According to the Physical Sciences Grade 10 CAPS document, the chemical change topic is made up of two subtopics, which physical and chemical change, and representation of chemical change, which takes two weeks to cover. Below are the designed lesson plans for the experimental group, which were given to the teachers to use for the duration of the lessons:

Week 1: <u>Chemical Change (Physical and Chemical Change)</u>

Engage

In the Engage phase, the teacher came up with ways of stimulating interest in the learners and activate their prior knowledge (Mupira and Ramnarain, 2018). In the current study, the teacher demonstrated the difference between chemical changes and physical changes by first mixing iron fillings with sulphur, and using a magnet to separate the mixture. Learners observed whether the mixture had any magnetic properties. Thereafter, the iron and sulphur mixture were heated in a test-tube. The demonstration stimulated the learners' interest as they observed the colour change of the mixture as it changed to bright red. Furthermore, the teacher brought a magnet to the mixture so as to determine whether the resulting product had any magnetic properties.

Explore

The explore phase followed were learners then worked in groups to explore their observations with assistance from the resources provided by the teacher, which included notes, as well as a worksheet to guide their exploration. According to Mamombe et al. (2020), the main aim of these probing activities is to provide the learners with experiences to develop skills and concepts. Furthermore, Warner and Myers (2017) add that, in the Explore phase, the teacher observes and guides the learners to provide them with the necessary scaffolding.

Explain

The Explain phase was characterised by learners' presentations of their discoveries linking them to the topic of the day through chemical and physical changes. After carefully analysing and observing the learners' presentations, the teacher corrected any noted misconceptions. Furthermore, the teacher then introduced the topic of physical and chemical change, where definitions, scientific terms, and examples were provided and discussed with the learners. According to Mamombe et al. (2020), during the explain phase, after observing and guiding, the teacher correct the noted misconceptions, explain concepts, and introduce scientific terms.

Elaborate

Elaborate is the fourth phase, during which learners were provided with activities that required them to make connections between the learned scientific concepts of physical and chemical change, and situations that they come across in their everyday lives. Moreover, the teacher also clarified any remaining misconceptions about physical and chemical change that learners still had. Warner and Myers (2017) emphasis that, during the Elaborate phase, learners make connections between new concepts, discoveries, principles, and real-world experiences, and apply these to a new situation, and they further argue that, unlike with traditional rote learning through memorisation, the application of concepts and knowledge allows learners to have an understanding of their learning.

Evaluate

The Evaluate phase was achieved by assessing learners on physical and chemical change concepts through posttest, which was administered in class by the teacher and focus group interviews that were driven by the researcher.

Week 2: <u>Chemical Change (Representation of Chemical Change).</u>

Engage

The representation of chemical change was introduced with either an experiment or demonstration of any reaction showing chemical change, especially one that would draw the attention of the learners. The teacher had to make sure that the learners were aware of the different phases of the reactants and the resulting product after the reaction, as well as the particles and mass of the reactants and products. This constituted the engage phase.

Explore

In the explore phase, learners were provided with notes and a worksheet to guide them in their class exploration of what they observed during the experiment or demonstration. The learners had to explore the name of the reactants and products, their phases, as well as their chemical formula. During the explore phase, the teacher moved around to maintain discipline and order in the classroom.

Explain

The explain phase then followed, where learners were given an opportunity to present in their own words their discoveries to the class. While they presented, the teacher made notes of all the misconceptions observed during the presentations. Thereafter, the teacher addressed the learners' misconceptions before introducing the topic. When introducing the topic, the teacher explained the scientific terms used in representation of chemical change, and then showed them how to write word equations and chemical equations, as well as how to balance chemical equations taking into account the law of constant composition in a chemical reaction.

Elaborate

The Elaborate phase is the fourth phase in the 5E-inquiry model. During the Elaborate phase, the teacher cleared any further misconceptions that learners had with regards to balancing chemical equations and using the law of constant composition. The learners were then given activities that expected them to apply the knowledge they learned about chemical equations, their balancing, and the law of constant composition, on problems based on examples of scenarios they came across on a daily basis.

Evaluate

The evaluate phase is the last phase in the 5E-inquiry model. This phase was characterised by the administration of a posttest to all the learners in the classroom as well as a focus group interview that involved only eight of the learners in the classroom.

3.5.4. Interviews

An interview is a conversation between an interviewer and participants, where the interviewer asks questions about the ideas, views, beliefs, behaviours, and opinions of the participant/s to collect the data he needs (Maree, 2007). Coileain (2020) describes interviews as resolute conversations aimed at determining the perspective of others

concerning a certain issue or situation. Patton and Cochram (2002) posit that interviews are like conversations that people normally have on daily basis, except that these conversations are guided by the researcher in order to collect data. Moreover, Creswell and Poth (2018) accentuate that an interview constitutes a qualitative way of gathering data. Interviews can be conducted either with an individual or a group of participants, depending on the research objectives and the kind of data required (Patton and Cochran, 2002). According to Maree (2007), properly conducted interviews can assist the researcher to gather valuable qualitative data from the participants. According to Nayak and Singh (2015), interviews are essential tools for collecting qualitative data that can be used together with data collected with other methods to investigate or study the research problem in detail. Despite them being labeled time consuming and difficult to analyse, interviews, if conducted properly, can provide a wide variety of advantages, which include providing high data validity, since data comes directly from the participants, larger number of responders as it takes place at an agreed-upon time, is flexible, and requires easily available equipment etc. (Nayak and Singh, 2015).
According to Maree (2007), interviews can be unstructured (open-ended), semi-structured, or structured.

i. Unstructured interviews (open-ended)

Unstructured or in-depth interviews are interviews that are normally carried out to explore a lesser known topic in order to gather as much information as possible about the perceptions and views of the participant/s (Patton and Cochran, 2002). According to Maree (2007), these kind of interviews can be done in series, where the participants are interviewed over a period of time. Maree (2007) adds that, in such interviews, the research participants can come up with their own solutions or give an in-depth account of events as some questions can be developed during the interviews.

ii. Semi-structured interview

According to Patton and Cochran (2002), semi-structured interviews are interviews with pre-determined list of open ended questions about the topic of interest. Maree (2007) describes semi-structured interviews as interviews that take less time to conduct and are mostly used in qualitative research to support data collected using other forms of data collection. Moreover, Maree (2007) cautions researchers to avoid being carried away by participants' stories that are not part of the topic, where if such occurs, the researcher must guide the participants back to the topic.

iii. Structured interviews

According to Patton and Cochran (2002), structured interviews or life histories are interviews that are in-depth, provide information about how events or things have changed overtime, and tell how people's lives have been affected by social changes in the community. Zion and Mendelovici (2012) adds that in structured interviews, the researcher designs and generates with a comprehensive list of questions which are asked in the same way so as to obtain answers that are phrased in the same way, and therefore do not support probing.

3.5.4.1. Semi-structured focus groups interviews

In this study, semi-structured focus group interviews were conducted after the participants had concluded all the lessons, and the post-test was written. The interviews were only conducted after permission was granted by all the relevant stakeholders, such as the district director, school principals, school governing body, and parents. According to Maree (2007), focus group interviews are interviews in which a group of five to 12 people is interviewed at the same time in order to gather information about a particular topic of interest. Focus groups allow a researcher to gather in-depth qualitative data in a short space of time (Bidi, 2018). According to Patton and Cochran (2002), features of focus group interviews include: selecting participants based on a certain sampling criteria while allowing probing, which are normally tape-recorded for transcription and analysis, and which are formal in nature, with the place and time arranged some time before the interview takes place. The focus group interviews followed a 'funnel structure', where the interviewer asked open-ended questions in order to 'break the eyes' of the participants (Maree, 2007). The interviews were aimed at gathering qualitative data on the perceptions of learners on their learning of chemical change under the traditional teaching method and the inquiry-based teaching method classroom environment. The use of interviews supplemented the findings of the pre-test and post-test, so as to provide in-depth understanding of the relationship between the inquiry-based teaching approach and the learners' conceptual understanding. The semi-structured interviews enabled the researcher to further investigate the perceptions of learners by allowing new ideas to emerge during the interviews (Mamombe et al. 2020). According to Patton and Cochran (2002), other benefits of conducting focus group interviews include the fact that they provide information about the social setup of the community of interest, and how opinions and accounts of events are developed in a social context. Furthermore, Maree (2007), adds that focus group interviews, especially semi-structured interviews, encourage probing, which allows new ideas to develop and a clarification of points that were not clearly understood. Even though focus group interviews are regarded as one of the best interview methods, Bidi (2018) indicates that the use of interview guides might prevent participants from giving enough information about a given topic. Moreover, Maree (2007) highlights that the small samples of focus groups may not represent the actual number of participants. Maree (2007) adds that, since participants in focus group interviews must be in the same place at the same time, participants in far areas might be late or not be able to attend the interviews.

Eight learners in each class were conveniently sampled due to the fact that only learners who were willing to remain behind after school for an hour were selected (Mamombe et al., 2020). There were four focus groups in total; two of which were from the experimental group, and the other two of which were from the control group. Thirty-two learners in total participated in the focus group interviews. The interview questions were designed according to perceptions indicators devised by Mensah-Wonkyi and Adu (2016) (with additions). During the interviews, the group of learners were asked questions based on learners' cohesiveness, learners' co-operation, teacher support, learners' confidence in the topic, and knowledge gain. The interviews took approximately 60 minutes each. More time was given for the interview so to ensure that the participants are not rushed and talked freely about their experiences. Assigning more time for data collection in qualitative research increases the credibility and validity of the study (Cope, 2014). The interview sessions were tape-recorded, but before the recording, participants were made aware of the fact that the interview are recorded prior the interview session (Bidi, 2018).

3.6. POPULATION AND SAMPLING

3.6.1. Population

Casteel and Bridier (2021) distinguish between the concepts of population of interest and target population. According to Struwig and Stead (2017), a population of interest is a group of people that contain features that the researcher wants to study and about which to generalise study results. Casteel and Bridier (2021) describe a target population as individuals, groups of people or organisations that have characteristics that the researcher wants to study, and the results of the research will be generalised. Meanwhile Shukla (2020) describes the population of interest as a group upon which the results of a study are to be based. The target population is defined as a specific group of possible participants that is within the population of interest that is conceptually bound, and has the unique characteristics that the researcher is interested in (Casteel and Bridier, 2021). Casteel and Bridier (2021) add that, normally, the participants of a study are sampled from the target group. On the other hand, Casteel and Bridier (2021) advise that the researcher must clearly identify the boundaries of the population of interest so as to avoid having participants who do not add any value in the study.

The population of interest of the current study comprise secondary schools that are within the Mgwenya and Sikhulile circuits, under the Ehlanzeni School District, and have Physical Sciences Grade 10 classes. The schools of interest were selected based on being township and semi-township schools respectively found in the Ehlanzeni region. There were 20 schools that made up the population of interest. The target population was made up of four schools that have single Grade 10 Physical Sciences class, with one science educator, are no-fee schools, have semi-furnished laboratories, and having approximately 40 learners in the Physical Science class.

3.6.2. Sample

A sample refers to a group that is selected to represent the population it was selected from (Shukla, 2020). According to Thomson (1999), a sample is selected when it is impractical to study the whole population, which might be due to financial and time implications. Majid (2018) emphasises that a sample must be selected in such a way that it is statistically representative of the entire population, such that results of the study can be generalised to the entire population. Thomson (1999) adds that the results of a study can only be generalised to the entire population if the sample clearly represents all the characteristics of the entire population. Patton and Cochran (2002) posit that sample sizes vary based on the size of the population, but sample sizes in qualitative research are smaller than in quantitative studies. Thomson (1999) recommends that before selecting a sample, the following is taken into consideration:

i. The sample characteristics must be similar to those of the population from which the sample is drawn. In quantitative research, it is important that the sample resembles the population in order for the results of the study to be generalised to the entire population.
ii. The selection of the sample does not introduce sampling bias in the research. Sampling bias comes about as a result of a statistically flawed sampling technique. To reduce sampling bias, the sample must be statistically representative of the entire population.
iii. The sample size must be large enough. In quantitative studies, this means that the sample size is large enough to show any difference that may exist between different groups. In qualitative studies, it means that there is enough time or people to gather meaningful data and undertake an in-depth analysis.

According to Maree (2007), sampling methods can be grouped into two groups, namely, the non-probability sampling, which is made up of sampling methods that are mostly used in qualitative studies, and probability sampling, which comprises sampling methods that are mostly used in quantitative studies.

In the current study, both non-probability and probability sampling methods were used.

i. Convenience sampling – according to Shukla (2020), convenience sampling is a non-probability sampling technique that involves selecting the easily available and accessible participants. Casteel and Bridier (2021) posit that in convenience sampling, the study participants are normally selected based on their proximity to the researcher, and they generally share the same demographic and social background.

   Convenience sampling was used to select the Ehlanzeni School District out of the four school districts in Mpumalanga province. The Ehlanzeni School District was selected based on being closer to the researcher, and therefore the schools under the district will be accessible to the researcher. This will ensure that the researcher is able to move from one school to another with ease, and minimize fuel cost during the data collection period.

   Furthermore, convenience sampling was used to select eight learners who participated during the quantitative data collection period from each class for the focus group interviews. The learners were conviniencely sampled based on their availability after school since the interviews were conducted after school. Only learners who were willing to remain behind after school for one hour were selected.

ii. Purposive sampling – refers to a non-probability sampling technique where participants are intentionally selected, based on having the characteristics and traits required by the researcher (Castee and Bridier, 2021). According to Chivanga and Munyai (2021), in purposive sampling, researchers use their own judgment to select participants that they think are relevant to their studies, and will provide the required data.

   The Mgwenya and Sikhulile circuits in the Ehlanzeni School District were purposively selected based on the fact that they are respectively situated in township and semi-township communities which are the schools that the study focuses on. The schools in those circuits are situated in a similar geographical area, with similar social and ethical backgrounds.

Moreover, purposive sampling was used to select four high schools that have one Grade 10 Physical Science class, taught by one Physical Science teacher, no-fee-paying schools, have semi-furnished laboratories, and have approximately 40 learners in the science class from a pool of 20 high schools in Mgwenya and Sikhulile circuits. Selecting schools having such characteristics so as to ensure that the prior-treatment conditions of the treatment and control groups were as similar as possible and that any difference after the treatment would be solely attributable to the treatment.

iii. Simple random sampling – is a probability sampling technique where every individual in a targeted area has an equal chance of being selected to be part of the research (Majid, 2018). Since, according to this sampling technique, every subject has an equal chance of being selected, simple random sampling is described as a method that is unbiased and without prejudice (Shukla, 2020). Shukla (2020) adds that the randomness in this kind of sampling is key to ensuring equal chances for the possible participants to be selected, for instance, if there are 10 learners in a population of interest (*N*=10), then the chances of each one of those learner being selected will be 1/10, carrying the same probability for all the 10 learners to be part of the sample (*n*).

Since the current study understood learners in the same classroom as one unit, simple random sampling was used in order to assign the four classes in the four selected schools into the control and experimental groups. Of the four schools, two were randomly assigned to the control group, and the other two into the experimental group. Random sampling was chosen to assign the four participating schools in the experimental and control groups to minimise researcher's biasness since the researcher is familiar with the schools, by so doing increasing the validity of the study.

3.7. DATA ANALYSIS

3.7.1. Quantitative analysis: learners' test results

According to Jansen and Warren (2020), quantitative data analysis refers to the analysis of numerical data in order to answer a research question. Quantitative data analysis was conducted so as to analyse data obtained from learners' pre- and posttest results, in order to answer the first research question:

I. What is the effect of an inquiry-based teaching approach on Grade 10 learners' conceptual understanding of chemical change concepts in the Physical Sciences in comparison with the traditional teaching approach?

The data was analysed using descriptive and inferential data analysis methods:

3.7.1.1. Descriptive statistics

Descriptive statistics are described as a branch of statistical methods that involve summarising numerical raw data in tables, graphs, mean, mode, and median (Maree, 2007; Patel, 2009, and Samuels, 2020). In the current study, the raw pretest and posttest results were summarised into percentages, and the mean and variance was then determined. Summarising the data into percentages and determining the mean and variance of the data allowed for further analysis of the data. According to Ameer (2021), descriptive statistics involve a preliminary analysis of quantitative data, which usually converts the researcher's observations into numbers. Ameer (2021) further stated that descriptive analysis summarises the data in an orderly way so that it can be easy to analyse further using inferential statistics, which will result in the generalisation of the results of the study to the entire population and beyond.

The results were analysed further so as to determine the N-gain in the different conceptual understanding indicators in the pretest and posttest results of the experimental and control groups (Primanda et al., 2018). The N-gain scores were interpreted according to Meltzer (2002), as cited in Primanda et al. (2018).

3.7.1.2. Inferential statistics

According to Jansen and Warren (2020), inferential statistics is a quantitative data analysis method that allows for the results of the study to be generalised to the entire population of the study, and beyond. Moreover, Ameer (2021) emphasises the need for the sample to accurately reflect the entire population, so as to ensure the validity of the generalisation of the study findings to the entire population and beyond. The current study employed independent samples t-test and the paired samples t-test to determine the degree of significance between (independent samples t-test) and within (paired samples t-test) the data of the control group and that of the experimental group. Furthermore, the independently sampled t-test results allowed for the testing of the null hypothesis of the study.

I. t-test

The t-test for independent groups was utilised in the study to determine whether there was any significant difference in the level of conceptual understanding between the experimental and control groups. According to Jansen and Warren (2020), the aim of t-tests is to analyse and compare the means of two data sets in a study so as to determine any statistical significance difference that might exist between them.

A paired samples or dependent groups t-test was also conducted between the pretest and posttest means of the control group, as well as that of the experimental group. This was done so as to determine whether there was any statistical difference in the level of conceptual understanding between the pretest and posttest results of the control group, as well as between the pretest and posttest results of the experimental group. Ameer (2021) describes the t-test for dependent groups as a t-test that is done on two data sets from a population with similar characteristics.

3.7.2. Qualitative data analysis: focus groups interviews

The focus group interviews were carried out to answer the second research question in order to provide an in-depth understanding of the results obtained from the analysis of the quantitative data. The second research question was stated as follows:

I. What are the learners' perceptions on their learning of chemical change under the inquiry-based approach and the traditional based approach classroom environment?

Qualitative data gathering methods such as focus groups, interviews, and observations collect a large amount of data in a form that needs to be transcribed, coded, and analysed (O'Connor and Gibson, 2003). Data collected from the semi-structured focus group interviews was then analysed using thematic analysis. According to Patton and Cochran (2002), thematic analysis of data involves taking a closer look into the word data gathered in the focus groups or interviews for key repeating statements, and generating themes from the data that summarises all the different views and opinions collected from all the focus groups. Kawulich (2004) posits that qualitative data analysis generally entails direct involvement of the researcher in the data collection process, so as to be familiar with the data, identifying patterns and themes that may exist in the data, finding relationships between the data, and then summarising and presenting the findings. Meanwhile, Clarke and Braun (2012) note that the process of thematic analysis is a stepwise process, which respectively include acquaintance and immersion, creating themes, coding, explaining, and interpretation, and verification.

i. Acquaintance and immersion – during this step, the researcher familiarised himself with the collected data from the focus groups (Lacey and Luff, 2009). This was done by the researcher being immersed in the data during the focus group interviews, where the researcher engaged with the groups for a better understanding of the topic (Clarke and Braun, 2012). According to O'Connor and Gibson (2003), the researcher must pay attention to all the accounts of the interviewees during the focus group interviews, since some patterns and themes can be selected from such accounts.

ii. Creating themes – According to Patton and Cochran (2002), identifying themes involves not just summarising the data, but also making in-depth observations of the data so as to determine what exactly the interviewee meant about a certain statement before starting to identify themes from the interviews. Here, the researcher went through the interview transcripts and the notes, and summarised them in such a way that they were aligned with the pre-identified themes, which are: learners' confidence, teacher support, learners' cohesiveness, or cooperation, and knowledge gain. Other themes and subthemes were allowed to emerge during this step. All the identified themes provided in-depth data about the perceptions of the learners on their learning under the inquiry and traditional teaching models.

iii. Coding – Coding is a step in qualitative data analysis that involves meticulously reading through the transcribed data from interviews or observations, word by word, and dividing this into categories that can easily be analysed (Maree, 2007). O'Connor and Gibson (2003) caution that coding can only take place once repeated words and phrases have been identified from the data, as well as capturing of the ideas of the interviewees as they express themselves in the interviews has taken place. Patton and Cochran (2002) highlight that coding ought to be applied to all the data, so as to ensure that the data analysis focuses in all the gathered data, and not only a certain extract that may have caught the eye of the researcher. Coding the entire data set will also ensure thorough analysis of the data (Patton and Cochran, 2002). In the current study, after the creation of themes, the data was then assigned different codes, such that it was aligned to the identified themes. Some sub-themes were merged and incorporated into the main theme (O'Connor and Gibson, 2003).

iv. Explanation - the explanation step is comprised of further analysis and identification of themes by looking deeply into the collected data, so as to pave a way for the thematic analysis (Clarke and Braun, 2012). Clarke and Braun (2012) further add that, in the explanatory step, the researcher identifies and corrects mistakes that may have happened during the coding process.

v. Interpretation and verification – here, the researcher consolidated all the interpretations by finding common grounds in the data, providing explanations and definition of concepts (Lacey and Luff, 2009). Lacey and Luff (2009) further posit that, the direction that the researcher takes in this step is dependent on the research questions and the themes that emerged from the data. Clarke and Braun (2012) adds that as the researcher continues to thorough look into the data, further mistakes which were not picked up on the previous steps will be discovered and rectified.

3.8. VALIDITY AND RELIABILITY

3.8.1. Quantitative study: Pretest and posttest

The concepts of validity and reliability are normally used in quantitative research to evaluate the quality of a research study (Khalid, 2012). In the current study, both the validity and reliability of the pretest and posttest were tested before, during, and after their use. Surucu and Maslakci (2020) state that both the validity and reliability of the research instrument must be tested so to ensure that the research findings are correctly interpreted.

3.8.1.1. Validity

According to Khalid (2012), validity determines the accuracy of a data gathering instrument in measuring what it intends to measure. Surucu and Maslakci (2020) posit that validity also determines how well a measuring instrument perform its task. A data gathering instrument that shows a high level of validity means that the instrument measures what it aims to measure, and therefore, the data gathered using such instrument can be discussed and provide valid conclusions (Khalid, 2012).

To ensure validity in the current study, the pretest and posttest were designed according to the Physical Science CAPS curriculum, and some questions were taken from previous exam papers. The tests were then checked by the Physical Science curriculum implementer (CI) so as to determine whether the questions measured the five conceptual understanding indicators as expected. On his recommendation, changes and adjustments were made to the test questions.

3.8.1.2. Reliability

The reliability of the data gathering instrument refers to the measure of how consistent and repeatable the instrument can be found to be (Maree, 2007). Moreover, Khalid (2012), states that reliability is the consistency of an instrument in measuring something. Golafshani (2003) cautions that reliability does not only concerns the consistency of the results, but also emphasises the correct representation of the entire population in a study. The reliability of an instrument is achieved when the same results are achieved after using the same instrument at different times under the same conditions (Khalid, 2012). To get similar results at all times, one needs to be consistent with his application of the research methods, and must ensure that the research conditions are standardised (Khalid, 2012). The reliability coefficient of the tests was estimated using Kuder-Richardson formula 20 in order to determine whether all the test questions measured conceptual understanding (Njoroge et al., 2014). According to Zaiontz (2022), the Kuder-Richardson formula 20 test (KR-20) estimates the internal consistency measurements made up of dichotomous choices, such as multiple choice questions. Heidel (2022) adds that the KR-20 formula test is run and interpreted the same way as Cronbach’s alpha in Statistical Package for the Social Sciences (SPSS). According to EL-Uri and Malas (2013), the KR-20 reliability score is influenced by the difficulty of the test, the spread of the test marks, and the length of the test. In the current study, the reliability coefficient was calculated using the SPSS statistical package, where the Cronbach’s alpha was calculated and found to be 0.703. The reliability coefficient score of the tests indicate that the tests questions were reliable in measuring conceptual understanding as EL-Uri and Malas (2013) posits that a reliability coefficient that is greater than 0.70 indicates that the test is acceptable.

3.8.2. Qualitative study: focus groups interviews

3.8.2.1. Trustworthiness

Trustworthiness is described as the truthfulness, authenticity, and quality of one’s findings in qualitative research (Nowell, Norris, White and Mules, 2017). Meanwhile, Yilmaz (2013), describes trustworthiness as the level of confidence one places in the findings of a qualitative study, that can be enhanced by an evidence of the ability to minimise biases at all stages of the research. The level of trustworthiness can be increased by ensuring credibility, transferability, dependability, and confirmability (Libarkin and Kurdziel, 2002).

Credibility

According to Khalid (2012), credibility refers to the confidence that one has in the truth of the research findings. According to Korstjens and Moser (2018), credibility establishes whether the findings of a study are drawn from the correct data as given by the participants, and whether the data is correctly interpreted according to the participants' original views. Khalid (2012) recommends that the researcher must spend more time in the field, analyse the data correctly, and use triangulation to improve the credibility of his study. Moreover, Maree (2007) encourages the use of multiple data sources, stakeholder checking, and avoiding generalisation in order to enhance the credibility of a study.

To enhance the credibility of the current study, the researcher spent more time interacting with the participants so as to record the original views of the participants and ask questions as to when views were not clearly understood. Multiple data sources such as focus groups and tests were utilised in order to gather the data. The use of triangulation produced diverse data, which was then analysed and interpreted using different data analysis and interpretation methods. In view of further improving the credibility of the study, the researcher went back to the participants to confirm whether the data was analysed and interpreted in a way that does not distort their original views.

Transferability

Refers to the extent to which the research findings of one study can be applied to other studies (Khalid, 2012). Khalid (2012) adds that, unlike in quantitative studies, in qualitative studies the aim is to show that the findings may have any relevance and meaning when applied to different participants, contexts, or areas. According to Libarkin and Kurdziel (2002), the transferability of the research findings is dependent on the ability of the researcher to provide enough information about the settings and variables of his study, thereby giving other researchers detailed information about his study. As much as the researcher in the current study attempted to detail all the important information of the study such as the research setting, the different variables of the study, as well as the background of the participants, Libarkin and Kurdziel (2002) note that it is the prerogative of the future researcher as to whether or not to use the findings to his/her study, this is entirely independent on the opinion of the current researcher.

Dependability

Dependability refers to the stability of research findings over time (Libarkin and Kurdziel, 2002). According to Khalid (2012), the dependability of a study can be ensured by having detailed account of the methodology, research decisions, and the data collection and analysis methods. Khalid (2012) emphasises that detailed documented research methodology allows other researchers engaging in similar studies and using the same methods to compare findings between the studies. Korstjens and Moser (2018) adds that dependability can also be ensured by allowing participants to review the interpretation, recommendations, and findings of the study, therein to be certain that they are all supported by the participants' original statements. In this study, an audit trail was developed, which contained detailed information about the research process, including information about the data gathering methods and steps involved, as well as a stepwise account of the approaches to data analysis and interpretation. Furthermore, the participants were allowed to comment on the analysis and interpretation of the data.

Confirmability

According to Libarkin and Kurdziel (2002) confirmability refers to the measure of the degree of subjectivity in a study. Korstjens and Moser (2018) describe confirmability as the extent to which the findings of a study can be corroborated by other researchers. No matter how much effort can be put in a study, it is impossible to achieve perfect objectivity (Khalid, 2012; Libarkin and Kurdziel, 2002). Despite the fact that it is impossible to attain total confirmability in a study, Libarkin and Kurdziel (2002) encourages qualitative researchers to always show that interpretations and analysis are free from subjectivity and always control biases. This could be achieved by keeping all study records such as original interview notes and transcripts, and also must allow other researchers to review the process data analysis and interpretation (Libarkin and Kurdziel, 2002). In this study, subjectivity was ensured by keeping a paper trail, with all the important information of the study for possible review by other researchers.

3.9. ETHICAL CONSIDERATION

Ethical consideration in research refers to designs and practices that guides a research study, that scientists and researchers must adhere to when collecting data from participants (Bhandari, 2021). When one conducts research that involves human participants there are key considerations that one must adhere to in order to protect the rights of participants, improve research validity, and maintain scientific integrity (Bhandari, 2021). The key considerations in any research study include consent, and confidentiality and anonymity (Patton and Cochran, 2002).

3.9.1. Consent

Consent is one of the fundamental principles of research ethics which is intended to ensure that anyone who decides to participate in a study does so freely and without being unfairly pressurised to participate (Patton and Cochran, 2002). In the current study, the main ethical considerations were followed before any data was collected, where ethical clearance was requested and granted by the UNISA College of Education's Ethics Committee. Thereafter, permission to conduct the research in the selected schools was requested and granted by the Ehlanzeni District director (Appendix A), school principals (Appendix D), and teachers (Appendix E). Consent was informed, where learners as possible participants were verbally briefed about the aim and objectives of the study before they were given consent letters for their parents which explained the study in detail in order to consent their children's involvement. Assent letters (Appendix H) were then distributed to the learners as possible participants of the study in order for them to assent their involvement in the study.

3.9.2. Confidentiality and anonymity

According to Khalid (2012), in any research study, it is the responsibility of the researcher to assure the possible participants that everything will be confidential, their identities and rights would be always protected, and their responses would only be utilised for research purposes and would not be passed on to any other person. In this study, the researcher ensured confidentiality by ensuring that the learners' names, their identities, and their schools names were not disclosed to any one and did not appear anywhere in the reporting of the findings of the study. The learners were also informed that hard copies of the pretest and posttest answers would be stored by the researcher for a period of five years in a locked cupboard in the researcher's work office for future research or academic purposes, while electronic information would be stored on a password protected computer. After five years, the stored tests scripts and interview notes will be shredded and the interview electronic copies as well as other soft copies of the collected data will be permanently deleted from a hard drive through the use of a relevant software program. Moreover, the researcher ensured anonymity by assigning codes to the participants and their schools, which they used during the tests and during the focus group interview sessions.

3.10. CONCLUSION

The chapter discussed extensively the methodology of the study, which entails the approach and design adopted, the population and sampling methods involved in the study, data gathering and analysis methods, as well as the ways used to strengthen the validity and reliability of the study. In a nutshell, the study utilised quantitative and qualitative approaches to gather and analyse data in order to answer the research questions and fulfill the aim of the study. The interviews were conducted to support the quantitative findings. Probability (simple random sampling) and non-probability (convenience and purposive) sampling methods where used select the population of interest and assign the schools into experimental and control groups. Lastly, the chapter discussed consent, confidentiality and anonymity, as the main ethical aspects to be always considered when engaging in research involving human participants. The next chapter presents the analysis, interpretation, and discussion of the research findings.

CHAPTER 4

DATA ANALYSIS, INTERPRETATION AND DISCUSSION

4.1. INTRODUCTION

The previous chapter detailed the procedures followed in gathering the data that will be analysed so as to provide answers to the research questions. The aim of this chapter is to analyse, interpret, and discuss the findings obtained from the data in order to provide answers to the research questions and to test the hypothesis of the study. The data collection process took three weeks, with the first two weeks utilised to gather quantitative data, and the other week used to gather qualitative data from focus groups interviews. Marks from the pretest and posttest were used to gather quantitative data from 142 Grade 10 Physical Sciences learners from four township and semi-township schools, which where purposively selected from a population of interest made up of high schools under the Ehlanzeni School District, specifically Mgwenya and Sikhulile circuits. Of the 142 participants, 69 where from two schools, which were randomly selected as the control group, and 73 where from two schools, randomly selected as the experimental group. Thirty-two participants, 16 from the control group and the other 16 from the experimental group, were conveniently selected to participate in the focus groups interviews. The quantitative data was analysed using descriptive statistics in a form of graphs, percentages, mean scores, standard deviation scores, and the N-gain scores. Furthermore, the descriptive statistics were supported with paired samples and independent samples t-tests, which were conducted to further analyse the data so to answer the first research question and to test the null hypothesis of the study, as per the first research question:

What is the effect of an inquiry-based teaching approach on Grade 10 learners' conceptual understanding of chemical change concepts in Physical Sciences in comparison with the traditional teaching approach?

The null hypothesis with regards to the question was stated as follows:

H_0 = There is no statistically significant difference in conceptual understanding of chemical change between Grade 10 learners taught with an inquiry-based teaching approach and those taught with the traditional teaching approach in the posttest results.

The null hypothesis was tested at significance level, **$\alpha = 0.05$**

The data generated from the focus groups interviews was used to answer the second research question which was stated as follows:

What are the learners' perceptions on their learning of chemical change under the inquiry-based approach and the traditional based approach classroom environment?

The reliability and validity of the qualitative data gathering and analysis process was established by ensuring the trustworthiness of the process. This was done by spending more time analysing the data, the use of multiple data sources, such as tests and interviews, going back to the participants with the analysed data to confirm if their original views were not distorted in any form, keeping an audit trail and paper trail of the whole process, and triangulation of the research findings.

On the other hand, in the quantitative data gathering and analysis process, validity was established by designing the tests questions according to the Physical Sciences CAPS curriculum requirements, use of questions from moderated previous question papers, and by getting the opinion of a Physical Sciences curriculum implementer about the suitability of the questions to the Grade 10 learners and their ability to measure conceptual understanding. Moreover, reliability of the tests was established by measuring their reliability coefficient using the KR-20 in order to determine whether all the questions measured conceptual understanding. A reliability coefficient of 0.703 was obtained in the study, which meant that the research questions were reliable in measuring conceptual understanding.

4.2. ANALYSIS AND DISCUSSION OF QUANTITATIVE RESULTS: PRETEST AND POSTTEST

The data collection period was aligned with the allocated time of the chemical change topic in the annual teaching plan (ATP), so to ensure that the study did not negatively impact the teaching time and cause inconvenience to teachers and learners. The quantitative data gathering period commenced with a pretest, which was written on the first day of data collection by participants in both the experimental and control groups. The pretest had 10 MCQ questions of two marks each, where two questions (4 marks) were allocated for each indicator, meaning that all the five indicators of conceptual understanding were allocated four marks each. After the pretest, learners in both groups were taught the chemical change topic for two weeks, with the experimental group taught with the 5E inquiry-based lesson plan, while the control group was taught using the traditional teaching methods. A posttest structured in a way similar to the pretest was then written by learners in both groups on the last day of the lessons. All the learners' scripts were collected, marked, and recorded by the researcher. When marking, the marks obtained by each learner out of 20 were divided into five according to the five conceptual understanding indicators, with marks allocated for 1 representing the indicator 'interpret', 2-compare, 3-explain, 4-inference, and 5-classify, as depicted in Figure 4.1.

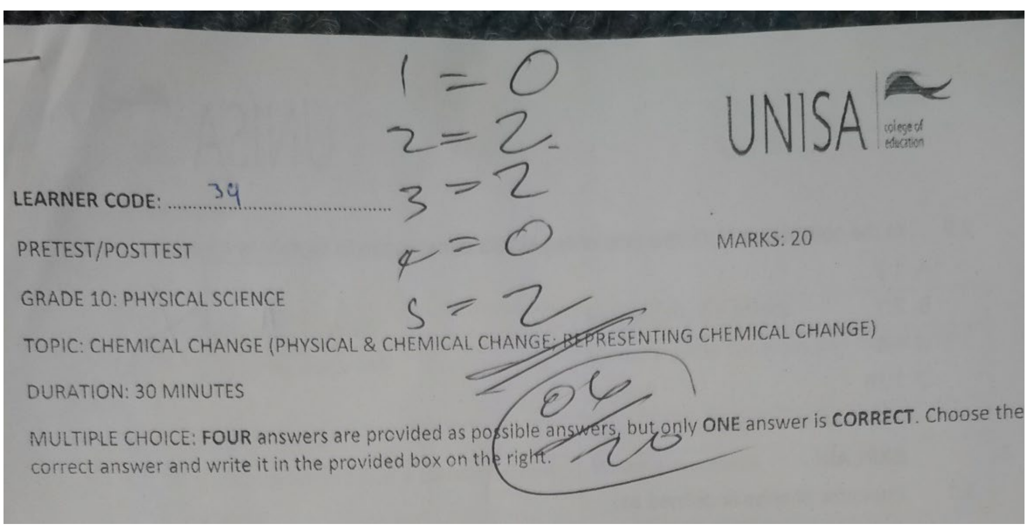


Figure 4.1: Excerpt of a learner's answer sheet indicating mark allocation

On the recording sheet, the marks obtained by individual participants were recorded and grouped according to the group (experimental or control) to which the participant belonged. The marks in each group were further grouped (Table 4.1 and Table 4.2) and added using Microsoft Excel, according to the five conceptual understanding indicators.

Table 4.1: Summary of raw marks obtained per indicator in the experimental group

Conceptual understanding indicator	Total mark expected in each indicator (4 x 73)	Total mark obtained (Pretest)	Total mark obtained (Posttest)
Interpret	292	70	180
Compare	292	66	98
Explain	292	148	198
Inference	292	112	220
Classify	292	88	132
TOTAL	**1460**	**484**	**828**
MEAN (N=73)	**20**	**6.63**	**11.34**
STANDARD DEVIATION	**0**	**33.90**	**49.79**

Table 4.2: Summary of raw marks obtained per indicator in the control group

Conceptual understanding indicator	Total mark expected in each indicator (4 x 69)	Total mark obtained (Pretest)	Total mark obtained (Posttest)
Interpret	276	76	100
Compare	276	68	68
Explain	276	146	152
Inference	276	98	112
Classify	276	92	102
TOTAL	**1380**	**480**	**534**
MEAN (N=69)	**20**	**6.96**	**7.74**
STANDARD DEVIATION	**0**	**30.43**	**30.19**

The total mark of each conceptual understanding indicator in Table 4.1 and Table 4.2 was obtained by multiplying the total expected mark in each indicator, which is four marks (two questions of two marks each), with the total number of participants in each group (experimental or control). All the calculations were done in Microsoft Excel. Meanwhile, the total mark of each indicator in the pretest and posttest was attained by adding all the marks obtained by the participants in that indicator in each group. Thereafter, the mean and standard deviation scores of each indicator were calculated, and recorded in tables 4.1 and 4.2.

4.2.1. Descriptive analysis

Quantitative descriptive statistical analysis was employed in the current study to summarise, group, and compare the results of the experimental and control groups before and after the intervention, so as to determine if there was any relationship between conceptual understanding of chemical change and the teaching method employed (inquiry or traditional) in a science classroom. The results were grouped and summarised in tables in a form of percentages, the mean score, standard deviation, and N-gain scores. The marks obtained by the participants in each conceptual understanding indicator were combined together and compared between the control and the experimental groups. The N-gain scores were interpreted according to Meltzer (2002)'s interpretation model as quoted in Primanda et al. (2018):

Table 4.3: interpretation criteria of the N-gain scores

Gain value	Criteria interpretation
(g) > 0.70	High
$0.30 < g \leq 0.70$	Medium
(g) ≤ 0.30	Low

According to Mckagan, Sayre and Madsen (2017), the normalised gain (N-gain) is a rough way of determining the effectiveness of a teaching and learning approach on increasing the level of conceptual understanding. Mckagan et al. (2017) states that some of the advantages of the normalised gain scores (g) include the fact that they are able to determine the effect of different teaching approaches on conceptual understanding of learners in diverse learning institutions. According to Meltzer (2002), the N-gain scores can be calculated by determining the difference between the percentage obtained in the pretest and posttest by using the following equation:

$$g = \frac{(post)-(pre)}{100-(pre)}$$

In this study, the N gain scores were used to determine the effectiveness of the inquiry-based teaching approach on Grade 10 learners' conceptual understanding of chemical change in comparison to the traditional teaching approach. The percentages attained by the participants in each indicator in the pretest and posttest were used to determine the N gain score in that indicator. The N-gain scores achieved in each indicator were calculated in Excel using the Meltzer (2002) equation. The scores were then interpreted and recorded in Table 4.4 together with their interpretations.

Table 4.4: The percentages, mean scores, standard deviation, and N-gain scores of each conceptual understanding indicator in the pretest and posttest results

INDICATOR	**EXPERIMENTAL GROUP (N = 73)**				**CONTROL GROUP (N = 69)**			
	PRETEST(%)	**POSTTEST(%)**	**N-GAIN**		**PRETEST(%)**	**POSTTEST (%)**	**N-GAIN**	
			Score	**Criteria**			**score**	**Criteria**
Interpret	24.00	61.64	0.495	Medium	27.54	36.23	0.120	Low
Compare	22.60	33.56	0.137	Low	24.64	24.64	0.00	Low
Explain	50.68	67.81	0.347	Medium	52.90	55.07	0.0461	Low
Inference	38.36	75.34	0.600	Medium	35.51	40.58	0.0786	Low
Classify	30.14	45.21	0.216	Low	33.33	36.96	0.0544	Low
Mean score	**33.16**	**56.71**	**0.359**	**Medium**	**34.78**	**38.70**	**0.0600**	**Low**
Standard deviation	**11.60**	**17.16**	**0.191**		**11.03**	**10.94**	**0.0436**	

The performance of the learners was measured by comparing the percentages, mean scores, and the standard deviation of the marks obtained by the learners before the intervention with those they obtained after the intervention. The percentages achieved by the learners in each indicator were calculated in Excel using the raw marks in Table 4.1 for the experimental group and Table 4.2 for the control group. This was done by dividing the total raw mark obtained in each conceptual understanding indicator with the total raw mark expected and multiplying by 100. For example, the percentage for the indicator 'interpret' in the experimental group for the pretest was calculated by dividing the total raw mark (70) by the expected total raw mark in the experimental group (292) and multiplying the outcome by 100 to make it 24 percent. Furthermore, the percentages as well as the N-gain scores of the individual conceptual understanding indicators obtained by the learners in the experimental and control groups before and after the intervention were compared and recorded in Table 4.4. The N-gain scores obtained by learners in both groups were compared and interpreted using Meltzer (2002)'s model of interpretation, as cited in Primada et al. (2018).

The ability to interpret is the first conceptual understanding indicator as identified by Makhrus et al. (2021) ensures that learners are able to interchange the information they learned from one type to another. For example, a learner must be able to change a word equation into a symbol chemical equation or be able to retrieve information from a graph, table or diagram, and write it in word form. The ability to interpret is key in learning as it addresses the issue of misconceptions, as learners who can interpret information well are less likely to develop misconceptions (Makhrus et al., 2021). Even though the learners in both the experimental and control groups improved their interpreting abilities in the posttests, Table 4.4 shows that learners in the experimental group have an overall percentage improvement of 37.64%, while those in the control group only have an increase of 8.69 percent. Notably, the experimental group managed to achieve a percentage of 61.64 percent in the posttest, while the control group only achieved 36.23 percent. The analysis of the percentages of both groups is supported by the N-gain scores, which show that the experimental group had an N-gain score of 0.495 in comparison with the 0.120 obtained by the control group for the ability to interpret. The 0.495 obtained by the experimental group translates to a medium achievement, while the

0.120 of the control group translates to a low achievement. According to Primada et al. (2017), low achievement shows that the teaching method did not cause any improvement in the ability to interpret, while medium achievement shows a moderate improvement. The percentages and N-gain scores in Table 4.4 show that the inquiry-based approach increased the learners' ability to interpret more than do traditional teaching methods.

Table 4.4 shows that the ability to compare has the least improvement in the posttests when compared with the rest of the indicators. Comparing is defined as the ability to determine similarities or dissimilarities between two or more things being examined (Merriam Webster, 2022). The ability to compare also involves being able to find any relationship that exist or might exist between two concepts, phrases, diagrams, etc. under scrutiny (Primada et al., 2017). The ability to compare in the experimental group increased with 10.96% in the posttest, while that of the control group did not increase at all. Table 4.4 shows that comparing has the lowest improvement in the posttests when compared with the other indicators in both the experimental and control groups. Despite an improvement of 10.96% in the ability to compare in the experimental group, comparing has the lowest percentage in the posttest results (33.56%), and is the first indicator, followed by the ability to classify, that achieved a percentage that is below 50% in the experimental group. These results are also supported by the analysis of the N-gain scores in both groups. The ability to compare has an N-gain value of 0.137 in the experimental group and 0.000 in the control group. These N-gain values are also the lowest when compared with the other indicators in both groups. Moreover, the N-gain score interpretation of the ability to compare in both groups translates to 'low' improvement, which indicates that both teaching approaches did not result in any improvement when it comes to the ability to compare in learners.

Explaining is defined as the ability to clearly provide reasons for one's choice (Merriam Webster, 2022). In Table 4.4, the ability to explain has the largest percentage in the pretests of both the experimental (50.68%) and the control (52.90%) groups, meaning that prior ability to explain was higher than their prior abilities of the other conceptual understanding indicators in both groups. The results also reveal that learners in both groups were able to clearly explain concepts of chemical change prior to their learning of the concepts. Furthermore, the ability to explain is the only indicator that has a percentage that is above 50% in the pretests in both groups. Further analysis of the percentages indicate that, despite the higher percentage in the pretests, the ability to explain did not improve much in the posttests in both groups. The experimental group had an improvement of 17.13% in the posttest, while the control group had an improvement of 2.17% in the posttest. When analysing the N-gain scores of the experimental group (0.347) and the control group (0.0461), which respectively translate to medium and low improvement in the ability to explain, it can be concluded that an inquiry-based teaching approach does improve learners' explaining skills more than do the traditional teaching methods.

To show that learners have developed conceptual understanding of a certain topic, they must also be able to give relevant examples in relation to that topic. The learners' inferencing abilities were similar in both groups prior to the intervention, as the pretest results of both groups were within the same range, with the experimental group achieving a percentage of 38.36% and the control group obtaining 35.51 percent. This means that learners in both groups were at similar level in terms of their ability to infer before the experimental group received treatment. Table 4.4 shows that learners in the experimental group improved their inference abilities the most when compared with other conceptual understanding indicators. Furthermore, with a percentage of 75.34% in the posttest, the ability to inference was the only indicator to achieve above 70% in both groups. After interpretation, the ability to inference with an improvement of 36.98% is the second most improved indicator in the posttests. Learners in the control group improved their inferencing skill by only 5.07%, where it is possible to deduce that the inquiry-based approach improved the ability to inference more than did the traditional approaches. This deduction is supported by the analysis of the N-gain scores, which show that the ability to infer has the biggest score (0.600) in the experimental group, when compared to the control group's score of 0.0786. The N-gain score of the ability to infer in the experimental group is the largest N-gain score in both groups in the posttests. When interpreted, the N-gain scores obtained by learners in the experimental and control groups' shows that learners in the experimental group had a medium improvement, while those in the control group had low improvement in relation to their ability to infer.

According to Primada et al. (2017), the ability to classify is one of the indicators of conceptual understanding measured by testing for the ability to group words or phrases according to a certain criteria. Table 4.4 shows the learners' ability to classify prior to the intervention was similar in both groups, as indicated by the percentages achieved in the pretest. The experimental group achieved 30.14% in the pretest, while the control group achieved 33.33 percent. Both groups showed an improvement in the percentage achieved in the posttest, with the experimental group achieving an improvement of 15.07% and the control group achieving an improvement of 3.63 percent. The analysis shows that the inquiry-based approach improved the skill to classify in science learners more than did the traditional teaching approaches. Moreover, regardless of the improvement percentage achieved in the posttest results in both groups, both groups did not reach a percentage above 60% in the posttest, with the experimental group achieving a percentage of 45.21% while the control group only achieved 36.96 percent. Despite the improvement in the percentages achieved in the posttests of both groups, the N gain score analysis indicates that the experimental group's score (0.216) translates to a medium improvement in the ability to classify, while the control group's score (0.0544) translates to low improvement. This further indicates that an inquiry-based approach improved the ability to classify more than did the traditional teaching approaches.

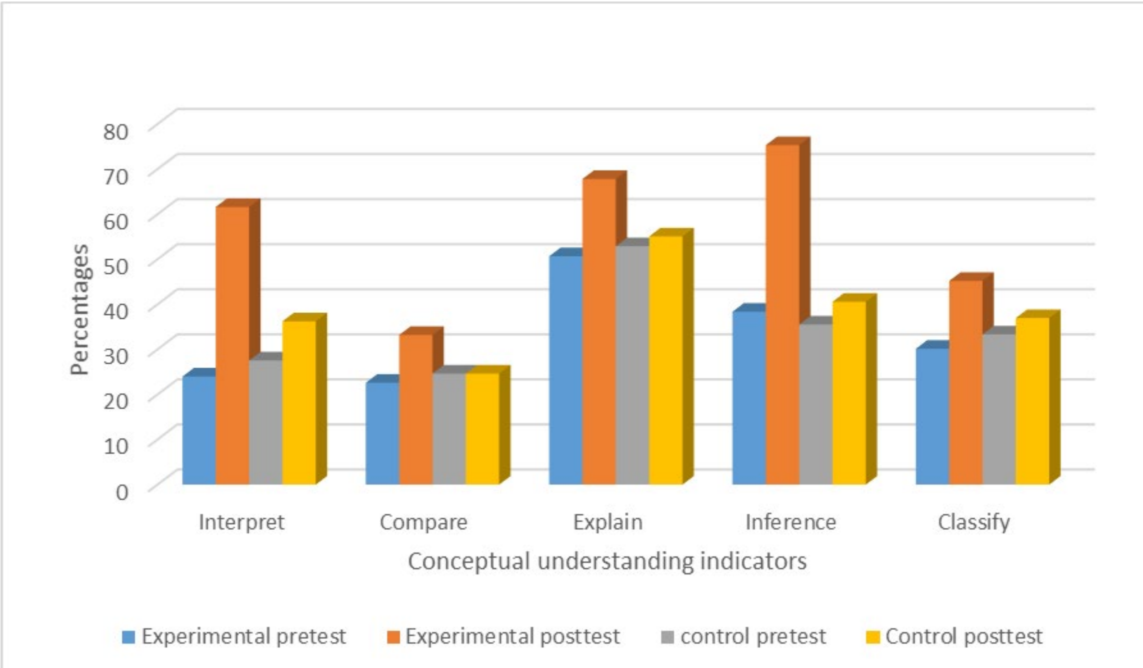


Figure 4.2: Comparison of the pretest and posttest results of the experimental and control groups

In Figure 4.2, the pretest percentages of both the experimental group and the control group are shown to be in close range within each other in each indicator. For example, the pretest percentages of both groups with regard to the indicator 'interpret' are within the 20-30% range. This trend is also observed with the other indicators, with the ability to explain obtaining the highest percentage in both groups in the pretests. The close range between the pretests of both groups suggests that they were at the same level of conceptual understanding of chemical change before the administration of the intervention in the experimental group. This analysis is important, because it implies that any change that is observed in the posttest is only attributed to the teaching approach implemented in the experimental and control groups. The mean scores of both groups corroborates the analysis that both groups were at the same level prior the administration of the treatment. The mean score of the experimental group (33.16) in the pretest is within the same range as that of the control group (34.78), with a difference of only 1.62 between the two groups. The experimental group has the highest percentage in all the conceptual understanding indicators in the posttest when compared to the control group, with the ability to infer obtaining the highest percentage. Despite this, with the exception of the ability to compare, all the other conceptual understanding indicators in the control group had higher percentages in the posttest than they did in the pretest. This indicates that the traditional teaching methods did improve the performance the learners in chemical change, even though in smaller proportions than the inquiry-based teaching approach. Further analysis of the posttests mean scores and the overall N-gain scores of each group show that the experimental group increased the performance of the learners in chemical change more than did the control group. The experimental group has an overall mean score of 56.71 in comparison with the 38.70 obtained by the control group in the posttests, as shown in Table 4.4. The mean scores shows that the inquiry-based approach increased the performance in chemical change more than the traditional teaching methods, with a difference of 18.01 between the means of the posttests of both groups. This outcome is further supported by the N-gain scores obtained from the mean scores of the pretests and posttests of both the experimental and control groups. The overall N-gain score of the experimental group is 0.359, while the control group has an N-gain score of 0.0600, which are interpreted respectively as medium gain and low gain, as indicated in Table 4.4. Therefore, one can conclude that the inquiry-based approach increases the performance of the learners in chemical change more than the traditional teaching methods.

4.2.2. Inferential analysis

The descriptive analysis of the results showed that the inquiry-based approach increased learners' abilities in all the five indicators of conceptual understanding more than the traditional approach. Even though the experimental group had much more improvement with regard to the individual indicators in the posttest, there was also some improvement observed in the control group in all but one indicator. On further analysis of the overall mean scores and N-gain scores, it was found that the inquiry-based approach increased the level of conceptual understanding of chemical change more than did the traditional teaching methods.

Paired samples t tests of the pretest and posttest raw scores of the individual indicators within a group were conducted so as to determine whether the improvement observed within each indicator in each group was significant enough to say that the teaching approach employed improves learners' skills with regard to that indicator. For example, the paired samples t-test was used to determine whether the improvement in the posttest with regard to the indicator, interpret, was significant enough to say that the teaching approach employed improves the skills to interpret in learners. Furthermore, paired samples t tests on the total raw scores obtained in pretest and posttest were also conducted so as to determine whether the increase in the pretest and posttest mean scores in each group was significant enough to say that the employed teaching method increased the level of conceptual understanding of chemical change.

Independent sample t-tests on the pretest raw scores of the individual conceptual understanding indicators of both the experimental and control groups were conducted to determine whether there was any statistically significant difference between the pretest results of each indicator in the experimental and control groups. This was done to determine whether the two groups were on the same level with regards to the abilities of learners in each indicator, so as to ensure that any observed improvement is ascribed to only the mode of teaching used. Independent samples t-tests were also done on the posttest raw scores of the individual indicators in both groups in order to determine if there was any statistically significant difference in the posttest results of each indicator between the two groups. The t-tests were to determine whether the improvement in the posttest with regards to the individual indicators was significant enough to say that it is due to the teaching approach used. Furthermore, the independent t test on the total raw scores of the posttest results was used to test for the null hypothesis of the study, which state that:

H_0 = There is no statistically significant difference in conceptual understanding of chemical change between Grade 10 learners taught with an inquiry-based teaching approach and those taught with the traditional teaching approach in the posttest results.

The null hypothesis was tested at significance level, **$\alpha = 0.05$**

All the t-test analysis were done using SPSS statistical software.

4.2.2.1. Analysis of paired samples t-test

I. Interpret

Interpretation is one of the indicators of conceptual understanding in learners. Learners who cannot interpret content well are likely to develop misconceptions, therefore the ability to interpret is key in eliminating or reducing misconceptions in learners.

Table 4.5: Comparison of the paired samples t-test results of both groups for the ability to interpret

Test	Groups	N	Mean	t-Value	P-value
Pretest	Experimental	73	0.959	-8.276	0.000
Posttest	Experimental	73	2.466		
Pretest	Control	69	1.101	-1.565	0.0611
Posttest	Control	69	1.449		

Since the p-value between the pretest and posttest mean scores of the experimental group in relation to the ability to interpret is p=0.000<0.05, the p-value suggests that there is statistical significant difference between the pretest and posttest mean scores of the ability to interpret. Therefore, the null hypothesis that there is no statistically significant difference between the pretest and posttest mean scores in relation to the ability to interpret is rejected. In contrast, the p-value of the control group is p=0.0611>0.05, which's suggest that there is no statistical difference between the pretest and posttest scores in relation to the ability to interpret in the control group. Based on the t-test analysis, despite the increase in the mean scores of both groups in the posttest, the experimental group had a greater improvement in relation to the ability to interpret than the control group. Therefore, it can be concluded that learners taught using an inquiry-based approach will interpret concepts related to chemical change better than will their counterparts in the control group.

II. Compare

Learners who evidence skill in comparing have the ability to find similarities or dissimilarities between groups, concepts, or topics that are being studied. These are some skills or abilities expected to learners to say they have developed conceptual understanding on a topic being studied. The results of the paired samples t-test shows that there was an increase of 0.438 in the posttest mean score in the experimental group while there was no increase in the control group. This analysis suggests that only the experimental group saw an improvement in the ability to compare while the control group did not have any improvement.

Table 4.6: Comparison of the paired samples t-test results of both groups for the ability to compare

Test	Groups	N	Mean	t-Value	P-Value
Pretest	Experimental	73	0.904	-2.193	0.0158
Posttest	Experimental	73	1.342		
Pretest	Control	69	0.986	0	0.500
Posttest	Control	69	0.986		

Further analysis of the paired samples t-test on the pretest and posttest mean scores of the ability to compare shows that there is statistical significant difference between the pretest and posttest mean scores of the ability to compare in the experimental group as the p-value is less than 0.05 ($p=0.0158<0.05$). Therefore, the null hypothesis that there is no statistical significant difference between the pretest and posttest mean scores of the ability to compare is rejected. On the contrary, the paired samples t-test results of the control group as indicated on Table 4.6 show that there is no statistical significant difference between the pretest and posttest mean scores of the ability to compare as the p-value is greater than 0.05 ($p=0.500>0.05$). In this regard, the null hypothesis that there is no statistical significant difference between the pretest and posttest mean scores of the ability to compare cannot be rejected. Moreover, the t-value of the experimental group is

-2.193, while that of the control group is 0. The comparison of the paired t test results in Table 4.6 suggest that the experimental group improved their ability to compare in the posttest while the control group showed no improvement at all. Therefore it can be concluded that learners taught with the inquiry-based approach will have better comparing skills in chemical change than those taught with the traditional teaching methods.

III. Explain

In Table 4.7, the mean scores between the pretest and posttest of the ability to explain indicate that learners in both the experimental and control group improved their ability to explain in the posttest, with those in the experimental group improving their mean score by 0.685, while those in the control group improved theirs by 0.087. Furthermore, the experimental group (-3.567) has a higher t-value than the control group (-0.327) which means that there is a bigger difference between the mean score of the pretest and posttest of the ability to explain in the experimental group than in the control group.

Table 4.7: Comparison of the paired samples t-test results of both groups for the ability to explain

Test	Groups	N	Mean	t-Value	P-Value
Pretest	Experimental	73	2.027	-3.567	0.000
Posttest	Experimental	73	2.712		
Pretest	Control	69	2.116	-0.327	0.372
Posttest	Control	69	2.203		

The p-value of the experimental group is $p=0.000<0.05$, which suggests that there is statistically significant difference between the pretest and the posttest mean scores of the ability to explain, rejecting the null hypothesis that there is no statistical difference between the pretest and posttest mean score of the ability to explain. The p-value indicates that there was a significant improvement in the posttest mean score of the ability to explain in the experimental group. On the other hand, the p-value of the control group (p=0.372>0.05) indicates that there was no statistical significant difference between the pretest and posttest mean score of the ability to explain, retaining the null hypothesis that states that there is no statistical significant difference between the pretest and posttest mean score of the ability to explain. This analysis indicates that the improvement in the mean score of the ability to explain in the posttest of the control group is not statistically significant enough to suggest that traditional teaching methods improve the ability to explain in learners. In conclusion, learners taught with the inquiry-based approach will explain chemical change concepts better than those taught chemical change with the traditional teaching methods.

IV. Inference

The ability to inference involves learners being able to give relevant examples related to the topic being studied. The comparison of the t-test results in Table 4.8 shows that both experimental and control groups improved their inferencing abilities in the posttest as both groups saw an increase in the posttest mean scores of the ability to inference. The experimental group had a mean score increase of 1.48, while the control group's mean increased by 0.203. Moreover, the experimental group had a t-value of -7.294 in contrast with -1.095 of the control group. Both the mean scores and t-values of the experimental and control groups suggests that the experimental group increased their inferencing abilities more than the control group.

Table 4.8: Comparison of the paired samples t test results of both groups for the ability to inference

Test	Groups	N	Mean	t-Value	P-Value
Pretest	Experimental	73	1.534	-7.294	0.000
Posttest	Experimental	73	3.014		
Pretest	Control	69	1.420	-1.095	0.139
Posttest	Control	69	1.623		

The p-value of the experimental group (p=0.000<0.05) in Table 4.8 indicates that there is statistical significant difference between the pretest and posttest mean score of the ability to inference, subsequently rejecting the null hypothesis that there is no statistical significant difference between the pretest and posttest mean scores of the ability to inference. The p-value suggests that the experimental group had a significant increase in the posttest mean score of the ability to inference. In contrast, the p-value of the control group (p=0.139>0.05) in Table 4.8 indicates that the null hypothesis is retained, since the p-value>0.05. Therefore, there is no statistically significant difference between the pretest and posttest mean scores of the ability to inference. Such analysis suggests that there was no significant increase in the mean score of the ability to inference in the control group. In conclusion, learners with the same level of inferencing ability, if taught with the inquiry-based approach, will have better inferencing skills than those taught with the traditional teaching methods.

V. Classify

Learners who have the ability to classify are able to group words, terms or phrases according to an identified criteria (Primada et al., 2017). The mean scores in Table 4.9 show that learners in both the experimental and control groups increased their classifying abilities in the posttest, with the experimental group increasing more than the control group. Table 4.9 shows that the experimental group has an increase of 0.493, while the control group has an increase of 0.145 in the posttest. Furthermore, the t-value shows that there is a bigger difference between the pretest and posttest mean scores of the ability to classify in the experimental group than in the control group.

Table 4.9: Comparison of the paired samples t-test results of both groups for the ability to classify

Test	Groups	N	Mean	t-Value	P-Value
Pretest	Experimental	73	1.315	-2.592	0.006
Posttest	Experimental	73	1.808		
Pretest	Control	69	1.333	-0.696	0.244
Posttest	Control	69	1.478		

The p-value of the experimental group, p=0.006<0.05 shows that there is a statistical significant difference between the pretest and posttest mean scores of the ability to classify, providing grounds to reject the null hypothesis that there is no statistically significant difference between the pretest and posttest mean scores of the ability to classify. This conclusion suggests that the experimental group has a statistical significant increase in the posttest mean score of the ability to classify. In contrast, the p-value of the control group, p=0.244>0.05 shows that there is no statistically significant difference in the pretest and posttest mean scores of the ability to classify, consequently providing no grounds to reject the null hypothesis. Therefore, the p-value suggests that there was no statistical significant difference in the pretest and posttest mean scores of the ability to classify. In conclusion, the comparison of the mean score, t-value and p-value of the experimental and control groups shows that learners who are taught chemical change with the inquiry-based approach will classify words, terms, or phrases related to chemical change better than those taught with the traditional teaching methods.

VI. Comparison of the paired samples t-test on the overall mean scores of the pretest and posttest of the experimental and control groups

The paired samples t-tests were conducted in order to determine if the difference in the pretest and posttest is significant enough in each group to say the model of teaching used is effective for teaching Grade 10 chemical change topic in Physical Science. Table 4.10 compares the t-test results of the experimental and control groups before and after the lessons. The t-test results include the comparison of the mean scores and standard deviation before and after the lessons, as well as the t value and P value of the pretest and posttest of the experimental group.

The overall mean scores of the experimental and control groups in Table 4.10 shows that the mean score of the experimental group increased more than that of the control group in the posttest. In comparison, the mean score of the experimental group increased by 4.712, with a t-value of -13.822, meanwhile the mean of the control group increased by 0.782 with a t-value of -5.027. The increase in the mean scores and t-values in both groups indicate that the inquiry-based approach used in the experimental group and the traditional teaching methods increased the performance of the learners in chemical change. However, the inquiry-based approach increased the performance more than the traditional teaching approach, as it has a higher increase in the mean scores and higher t-value.

Table 4.10: Comparison of the paired samples t test results of both groups for conceptual understanding

Test	Groups	N	Mean	t-Value	P-Value
Pretest	Experimental	73	6.630	-13.822	0.000
Posttest	Experimental	73	11.342		
Pretest	Control	69	6.957	-5.027	0.000
Posttest	Control	69	7.739		

Tables 4.5, 4.6, 4.7, 4.8 and 4.9 showed that the mean scores of the conceptual understanding indicators in the posttest of the experimental group increased more than did the mean scores of the control group. The trend led to the analysis that the mean scores of the conceptual understanding indicator increased more significantly in the posttest in the experimental group than in the control group. In contrast, Table 4.10 shows that there is a statistically significant increase between the pretest and posttest overall mean scores in both the experimental and control groups, subsequently rejecting the null hypothesis that there is no statistically significant difference in the pretest and posttest overall mean scores in the experimental and control groups. These findings suggest that even though the inquiry-based approach increased the level of conceptual understanding of chemical change more than does the traditional teaching approach, both teaching approaches significantly increased the mean scores of the posttest rather than the pretest. Further analysis was conducted to determine whether the increases observed in the mean scores of the posttest within a group is significant when compared with another group, so to determine a teaching method that significantly improves the level of

conceptual understanding of chemical change. This was done by conducting independent samples t-tests on the posttest mean scores of the experimental and control groups.

4.2.2.2 Independent samples t-test analysis

Independently sampled t-tests on the pretest raw scores of the individual conceptual understanding indicators of both the experimental and control groups were conducted to determine whether there was any statistical significant difference between the pretest results of each indicator in the experimental and control groups. This was done to determine whether the two groups were on the same level with regards to the abilities of learners in each indicator to ensure that any observed improvement is ascribed to only the mode of teaching used. White and Sabarwal (2014) emphasise the importance of ensuring that the characteristics of the control and experimental groups before the administration of the intervention to the experimental group are as similar as possible to guard against selection bias, which would raise the question as to whether the difference in the results is due to the intervention, or results from the difference in characteristics of the groups before the intervention. Independent samples t-tests were also done on the posttest raw scores of the individual indicators in both groups to determine whether there was any statistically significant difference in the posttest results of each indicator between the two groups. The t-tests served to determine whether the improvement in the posttest with regards to the individual indicators was significant enough to say that it is due to the teaching approach used. Furthermore, the independent t-test on the total raw scores of the posttest results was used to test for the null hypothesis of the study, which state that:

H_0 = There is no statistically significant difference in conceptual understanding of chemical change between Grade 10 learners taught with an inquiry-based teaching approach and those taught with a traditional teaching approach in the posttest results.

The null hypothesis was tested at significance level, **$\alpha = 0.05$**

I. Interpret

The pretest mean scores of the ability to interpret in Table 4.11 shows that both the experimental and control groups have comparable mean values, with a difference of only 0.142 between the two values. Moreover, both groups have a t-value of only 0.701, which indicates that a small difference exists between the two mean scores. The results of both the mean scores and t-value suggest that the experimental and control groups were on the same level in relation to the ability to interpret before the intervention. In comparison, a difference of 1.017 exists between the posttest mean scores of both groups, with a t-value of 5.607. The mean scores and t-value suggest that the learners were not at the same level of the ability to interpret in the posttest, with the experimental group being at a higher level.

Table 4.11: Comparison of the independent samples t-test results of both groups for the ability to interpret

Test	Groups	N	mean	t-Value	P-Value
Pretest	Experimental	73	0.959	0.701	0.242
	Control	69	1.101		
Posttest	Experimental	73	2.466	5.607	0.000
	Control	69	1.449		

The independent samples t-test on the mean scores of the ability to interpret in the pretest on Table 4.11 indicate that there is no statistically significant difference between the mean scores of the experimental and control groups as the p-value is $p=0.242>0.05$. The p-value provides grounds to retain the null hypothesis that there is no statistically significant difference between the pretest mean scores of the ability to interpret in both the experimental and control groups. The mean scores, t-value and p-value of the pretest results all suggest that learners in the experimental and control groups were at the same level in terms of their ability to interpret before the administration of the intervention to the experimental group. This analysis stands in contrast to that of the posttest results between the two groups, as there is a bigger difference between the mean scores and there exists a bigger t-value (5.607) between them. Furthermore, the p-value (p=0.000<0.05) of the posttest mean scores of both groups provide grounds on which to reject the null hypothesis that there is no statistical significant difference between the mean scores of the ability to interpret in both the experimental and control groups. This means that there is significant difference between the mean scores of the two groups in the posttest. Analysing Table 4.11, one can deduce that learners in both groups were at the same level with regards to their ability to interpret before they were taught chemical change, and therefore, that the observed difference in the experimental group is entirely due to the inquiry-based teaching approach. In that regard, it can be concluded that learners taught chemical change with the inquiry-based approach will have better interpreting skills than those taught with the traditional teaching methods.

II. Compare

In Table 4.12, the experimental group has a mean score of 0.904 while the control group has a mean score of 0.986 in the pretest. Moreover, the mean scores constitute a mean score difference of 0.082 with a t-value of -0.436. The smaller difference between the means and a smaller t-value suggests that the difference between the two means is not a significant one, and therefore one can deduce that there is no difference between the mean scores of the ability to compare in the pretest of both groups. This means that the learners in both groups were at the same level with regards to the ability to compare before the intervention. On the other hand, Table 4.12 shows a bigger difference of 0.356 between the means and a t-value of 1.828 in the posttest results. The bigger difference between the mean scores of the two groups and the bigger t-value suggests that there is a significant difference between the mean scores, implying that the level of the ability to compare was not the same between the two groups after the administration of the intervention to the experimental group.

Table 4.12: Comparison of the independently sampled t-test results of the ability to compare

Test	Groups	N	mean	t-Value	P-Value
Pretest	Experimental	73	0.904	-0.436	0.332
	Control	69	0.986		
Posttest	Experimental	73	1.342		

			1.828	0.0349
Control	69	0.986		

To determine if indeed the learners in both groups were on the same level of the ability to compare before the intervention, further analysis of the p-value of the pretest means was conducted. The pretest means has a p-value of $p=0.332>0.05$, which indicates that the null hypothesis that there is no statistically significant difference between the mean scores of the ability to compare in both groups in the pretest cannot be rejected, but instead, that they are therefore retained. The p-value confirms that learners in both the experimental and control groups were at the same level of the ability to compare before the intervention, and therefore that any improvement in the posttest is attributed to the mode of teaching alone. In contrast, the p-value of the posttest mean scores, $p=0.0349<0.05$ provides grounds for the rejection of the null hypothesis, as the p-value is greater than 0.05. The analysis shows that there is a statistically significant difference between the mean scores of both groups in the posttest. In that regard, it can be deduced that learners who are taught chemical change with the inquiry-based teaching approach will compare concepts of chemical change better than those taught using the traditional teaching methods.

III. Explain

Learners who can clearly provide reasons for the choices they made are said to have developed skills to explain. The ability to clearly explain a concept is one of the prerequisites for conceptual understanding. Table 4.13 indicates that learners in both groups were at a slightly similar level of the ability to explain before the intervention as they had a mean score difference of only 0.089 and a t-value of -0.407. The mean score difference and the t-value suggest that there was no significant difference between the pretest mean scores of both groups. This analysis stands in contrast with that of the posttest results, as shown in Table 4.13. In the posttest, there was a higher mean score difference of 0.509 and a higher t value of 2.192. The higher mean score difference and t-value suggest that learners in both groups were at different levels of the ability to explain after the intervention, with the experimental group at a higher level than the control group.

Table 4.13: Comparison of the independent samples t test results of the ability to explain

Test	Groups	N	mean	t-Value	P-Value
Pretest	Experimental	73	2.027	-0.407	0.342
	Control	69	2.116		
Posttest	Experimental	73	2.712	2.192	0.0150
	Control	69	2.203		

The mean score and t-value analysis is supported by the analysis of the p-value. In the pretest, the p-value is $p=0.342>0.05$, which suggests that there is no statistically significant difference between the experimental and control group's mean scores. The p-value suggests that both groups were at the same level of the ability to explain before the administration of the intervention. On the other hand, the independent samples t-test on the posttest mean scores shows that $p=0.0150<0.05$, which implies that there is statistically significant difference between the mean scores of the experimental and control groups. Such analysis suggests that both groups were not at the same level of the ability to explain after the intervention, with the experimental group having a higher ability to explain than the control group. One can therefore conclude that learners learning under an inquiry-based approach environment will explain concepts of chemical change better than those learning under the traditional teaching methods environment.

IV. Inference

Being able to provide relevant examples related to a topic under study indicates that one has developed skills of inference. Table 4.14 shows that both the experimental and control groups were at a similar level of the ability to inference as they had a smaller difference between their mean scores and a lower t-value in the pretest. The experimental and control groups had a mean score difference of 0.114 and a t-value of 0.561, which both suggest that the learners in both groups were at the same level with regards to the ability to infer before the administration of the intervention to the experimental group.

Furthermore, a p-value was calculated to determine whether there is a statistical significant difference between the experimental and control group mean scores in the pretest. The p-value is important in order to determine whether the difference between the mean scores is statistically significant enough to conclude that both groups were different before the intervention. As indicated in Table 4.14, the p-value of the pretest means is $p=0.288>0.05$, which signifies that there is no statistical significant difference between the groups before the intervention, subsequently providing grounds to retain the null hypothesis that there is no statistical significant difference between the experimental and control groups' mean scores in the pretest.

Table 4.14: Comparison of the independent samples t-test results of the ability to inference

Test	Groups	N	mean	t-Value	P-Value
Pretest	Experimental	73	1.534	0.561	0.288
	Control	69	1.420		
Posttest	Experimental	73	3.014	7.162	0.000
	Control	69	1.623		

The mean score difference between two groups tells how much different the groups are from one another, meanwhile the t-value reveals how big the difference is between the two groups. With a mean score difference of 1.391 and a t-value of 7.162, the ability to inference has the largest mean difference with the t-value in the posttest when compared to the pretest. This indicates that there was a much larger difference between the mean scores of both groups, with the experimental group having a larger mean score than the control group. This analysis is supported by the p-value as shown in Table 4.14 ($p=0.000<0.05$), which provides grounds for rejecting the null hypothesis that there is no statistically significant difference between the experimental and control groups mean scores of the ability to inference. The analysis of the p-value suggests that learners taught chemical change with an inquiry-based approach, will inference concepts related to chemical change better than those taught using the traditional teaching methods. Moreover, the ability for inference has the largest mean score difference in the posttest when compared to other indicators, signifying that the inquiry-based approach increased the ability to inference in learners more than any other conceptual understanding indicator.

V. Classify

Learners who have developed conceptual understanding of a topic must be able to classify concepts, phrases, words, and etc. related to the topic. In Table 4.15, the pretest mean score of the experimental group is 1.315 and that of the control group is 1.333, with a mean score difference of 0.018. The lower t-value of -0.089 indicates that there was a smaller difference between the mean scores of the ability to classify in both groups. Together, the mean score difference and the t-value suggests that both groups were at the same level with regards to the ability to classify before the administration of the intervention. The same sentiment is shown by the p-value (p=0.464>0.05), which reveals that there is no statistical significant difference between the pretest mean score of the experimental and control groups. This result indicates that the learner classifying abilities were at the same level before the intervention. Such analysis contradicts that one of the posttest results. The posttest results show a mean score difference of 0.330 and a t-value 1.650, both of which indicate a higher mean score difference and t-value than the pretest. The difference in the means and t-value suggests that the level of the ability to classify increased in the posttest in both groups. It is notable that the p-value (p=0.0506>0.05) reveals that there is no statistical significant difference between the mean scores of both groups in the posttest, meaning that the null hypothesis that there is no statistical significant difference between the experimental and control groups' mean scores is retained. The p-value implies that both the inquiry-based approach and the traditional teaching methods increased the level of the ability to classify equally, where no method was superior when it came to developing classifying skills in learners.

Table 4.15: Comparison of the independent samples t test results of the ability to classify

Test	Groups	N	mean	t-Value	P-Value
Pretest	Experimental	73	1.315	-0.089	0.464
	Control	69	1.333		
Posttest	Experimental	73	1.808	1.650	0.0506
	Control	69	1.478		

Even though Table 4.4 and Figure 4.2 show that the inquiry-based approach increases the percentage of all the conceptual understanding indicators more than the traditional teaching methods, the difference of the increase in the indicator ‘classify’ is not statistically significant to say that the inquiry-based teaching approach increases the level of classifying in learners more than the traditional teaching methods.

VI. Testing for the study’s null hypothesis

To further analyse the effect of inquiry-based approach on conceptual understanding of chemical change, an independent t-test on the pretest and posttest total raw marks of both experimental and control groups was conducted to determine whether the learners were on the same level of conceptual understanding before the intervention and to test the null hypothesis of the study, which states that:

H_0 = There is no statistically significant difference in conceptual understanding of chemical change between Grade 10 learners taught with an inquiry-based teaching approach and those taught with the traditional teaching approach in the posttest results.

The null hypothesis was tested at significance level, **$\alpha = 0.05$**

Table 4.16: Comparison of the independent samples t-test results of conceptual understanding between the groups

Test	Groups	N	mean	t-Value	P-Value
Pretest	Experimental	73	6.630	-0.753	0.226
	Control	69	6.957		
Posttest	Experimental	73	11.342	7.405	0.000
	Control	69	7.739		

The mean score and t-value of both the experimental and control group as illustrated in Table 4.16 shows that there is no difference between the means of the two groups. With a difference of 0.327 and a t-value of -0.753, the learners in the two groups were at the same level of conceptual understanding before the intervention. Such analysis is supported by the p-value ($p=0.226>0.05$), which reveals that there is no statistical significant difference between the mean score of the two groups, meaning that the null hypothesis that there is no statistical significant difference between the mean scores of both groups in the pretest is retained. Having groups that are at the same level of conceptual understanding before the administration of the intervention ensures that there is only one independent variable, and therefore, that the change in the dependent variable will only be attributed to the manipulation of the independent variable. In Table 4.16, both the experimental and control groups saw an increase in their mean scores in the posttest, with the mean of the experimental group increasing by 4.712, meanwhile that of the control group only increases by 0.782. The t-value in the posttest jumped to 7.405 from -0.753, which suggests that there was a significant difference between the mean scores of the two groups after the intervention. In support of the means and t-value, the p-value ($p=0.000<0.05$) reveals that there is statistically significant difference between the mean scores of the experimental and control groups in the posttest. Therefore, the p-value provide grounds for the rejection of the null hypothesis of the study and the acceptance of the alternative hypothesis of the study, which state that:

H_A= There is statistically significant difference in conceptual understanding of chemical change between Grade 10 learners taught with an inquiry-based teaching approach and those taught with the traditional teaching approach in the posttest results.

This result suggests that despite the increase in the posttest mean scores in both groups and the fact that the ability to classify improved equally in learners in both groups, learners taught with the inquiry-based approach will have a higher level of conceptual understanding of chemical change than those taught with the traditional teaching methods.

4.2.3 Discussion of quantitative findings

The quantitative findings were discussed in order to determine the effects of the inquiry-based approach on Grade 10 learners' conceptual understanding of chemical change in Physical Sciences as to answer the first research question and test for the null hypothesis of the study. The discussion involves a discussion of findings made from descriptively analysed data and inferentially analysed data. The descriptive data was analysed using tables, graph, means, percentages, standard deviation and N-gain scores, meanwhile inferential analysis was conducted using paired and independent samples t-tests, in order to determine whether any increase observed in the posttest is statistically significant or not.

4.2.3.1 The effect of inquiry-based approach on conceptual understanding

I. *What are the effects of an inquiry-based teaching approach on Grade 10 learners' conceptual understanding of chemical change concepts in Physical Sciences in comparison with the traditional teaching approach?*

The descriptive analysis of the data as per Table 4.4 and Figure 4.1 suggest that both the experimental and control groups were at the same level of conceptual understanding of chemical change in relation to the different indicators of conceptual understanding. In Table 4.4, the pretest mean scores and percentages of both groups were at the same range, indicating that the learners in both groups obtained marks in the same range in the test. Such analysis is supported by the analysis of Figure 4.1, which shows that the pretest percentages for each indicator obtained by learners in both groups exist within the same range. For example, Figure 4.1 shows that the pretest percentages for the indicator ‘referencing’ are within the 30 – 40% range in both groups. In order to determine whether both groups were indeed in the same level with regards to the different indicators of conceptual understanding, independent samples t-tests on the different indicators were calculated. The results showed that there was no statistically significant difference between the mean scores of the different indicators between the two groups, as the p-values in all instances were greater than 0.05. Furthermore, the independent samples t-test on the total mean scores obtained in the pretest in both groups found that the p-value was greater than 0.05, which means that the learners in both the experimental and control groups were at the same level of conceptual understanding of chemical change prior the administration of the intervention in a form of a 5E inquiry-based lesson plan to the experimental group. Masilo (2018) and Mensah-Wonkyi and Adu (2016) argue about the importance of ensuring that both the experimental and control groups are at the same level, especially with regards to the knowledge of the topic of interest, so as to ensure that any improvement in the posttest is as a result of the intervention only. Babbie and Benaquisto (2002) add that ensuring that both groups are comparable before the administration of the intervention will minimise any threat to internal validity, which might threaten the ability to achieve valid conclusions at the end of the study. Furthermore, Babbie and Benaquisto (2002) state that the similarity between the control and experimental group must be such that it shows what the experimental group would be like if it had not received the treatment or intervention. The current research has statistically established that both the experimental and control groups were at the same level of conceptual understanding of chemical change prior to the administration of the intervention in a form of 5E inquiry-based lesson plan for the experimental group. This confirms that any improvement in the level of conceptual understanding on the experimental group is only attributed to the 5E inquiry-based lesson plan.

The study posits that the 5E inquiry-based lesson plan improved learners’ ability to interpret, compare, inference, and explain concepts related to chemical change better than the traditional teaching methods. This finding is based on the p-values of the independent samples t-tests conducted on the posttest mean scores of the individual indicators of conceptual understanding in both groups. The t-test determined that the p-value in all but one indicator is greater than 0.05, which provided grounds to reject the null hypothesis that there is no statistically significant difference between the mean scores of the individual indicators in both groups. The mean scores and p-value suggest that the learners in the experimental group experienced greater improvement with regards to all but one of the indicators of conceptual understanding when compared to those in the control group. A contrasting outcome was observed with regards to the ability to classify. Despite achieving a higher mean in the posttest in the experimental group, the independent samples t-test on the mean scores of the ability to classify resulted in a p-value (Table 4.15) greater than 0.05, which means that the null hypothesis that there is no statistically significant difference between the posttest mean scores of the ability to classify in both the experimental and control groups is retained. Therefore, it is notable that the mean score of the experimental group in the posttest is not significant enough to claim that learners in the experimental group have an increased ability to classify than their counterparts in the control group. This finding stands in contrast with those of Susilaningsih, Fatima and Nuswowati (2019) in their analysis of conceptual understanding of acids and bases, a science topic, where they found that the use of alternative teaching methods such as an inquiry-based approach improves all conceptual understanding indicators in learners. Their findings were also supported by those of Asfar and Asfar (2020), on their research about the use of inquiry-inspired case-based games to improve conceptual understanding. The authors found that learners in the experimental group achieved better scores in the posttest across all aspects of conceptual understanding than those in the control group.

Even though the mean score of the ability to classify did not significantly increase in the posttest in the experimental group, the study posits that the inquiry-based approach improves the level of conceptual understanding more than do traditional methods, meaning that learners taught with the 5E inquiry-based lesson plan would understand chemical change concepts better than those taught with the traditional teaching approach. This finding is based on the descriptive analysis of the mean scores and percentages of the posttest results of both groups (Table 4.4), which shows that the overall mean score (56.71) of the experimental group is higher than that of the control group (38.70). This indicates that learners in the experimental group obtained higher marks in the posttest than those in the control group. The mean scores were supported with the N-gain scores obtained by determining the difference between the pretest and posttest of each group. As shown in Table 4.4, the experimental group has an N-gain score of 0.359, which translates to medium gain, while that of the control group is 0.0600 and translates to low gain. The N-gain scores show that learners in the experimental group gained more knowledge related to the chemical change topic in the posttest, while those in the control group did not gain enough knowledge in the posttest. In support of these results, independent samples t-tests were conducted on the posttest mean scores of both the experimental and control groups to determine whether the increase was significant enough. In Table 4.16, the listed t-test results shows that the p-value of the posttest mean is less than 0.05 ($p=0.000<0.05$), which provides grounds to reject the null hypothesis of the study, which states that there is no statistical significant difference between the posttest mean scores of both groups. The p-value shows that learners in the experimental group had a higher level of conceptual understanding of chemical change than those in the control group. In support of these findings, various researchers in their studies on the effect of inquiry-approaches on learners' conceptual understanding found that the inquiry-based approaches increase the level of conceptual understanding of scientific and mathematics concepts more than do the traditional approaches (Aniisa and Rohaeti, 2021; Asfar and Asfar, 2020; Mensah-Wonky and Adu, 2016; Simsek and Kabapinar, 2010). In their study about the effects of inquiry-based approach on learners' conceptual understanding of the concept of chemical equilibrium, Aniisa and Rohaeti (2021) found that learners taught using an inquiry-based approach significantly increased their conceptual understanding of chemical equilibrium concepts more than did those taught with the traditional teaching methods. Moreover, Simsek and Kabapinar (2010) in their study investigating the effects of inquiry-based learning environment on conceptual understanding of matter, scientific process skills, and attitudes towards science not only found that inquiry-based learning environment positively impact conceptual understanding, but also concluded that inquiry also positively impact learners' scientific process skills.

In Table 4.10, the paired samples t-test results from the pretest and posttest mean scores indicate that both the experimental and control groups experienced a significant increase in the mean scores of the posttest in comparison with the pretest, as they both have a p-value that is less than 0.05 (p=0.000<0.05). These results are despite the paired samples t-test on the mean scores of the pretest and posttest results of each indicator in the control group, showing that there is no statistical significant difference in the pretest and posttest mean scores of each indicator, as the p-values are all greater than 0.05, as indicated in Tables 4.5-4.9. In that regard, the current study posits that despite the significant increase in the posttest mean score of the experimental group in comparison with the control group, the control group was able to significantly increase the posttest mean score in comparison with the pretest. This means that learners in both the experimental and control groups performed significantly better in their posttest when compared to the pretest. These findings stand in contrast with those made by Mensah-Wonky and Adu (2016), who found that the inquiry-based approach significantly increases the level of conceptual understanding in learners than the traditional approach, and that there is no statistical significant difference between the pretest and posttest mean scores (p>0.05) in the control group. Their findings suggest that the learners in the control group did not significantly increase their posttest mean scores in comparison to the pretest mean scores. Their findings stand in contrast with the current study findings and those of Mamombe et al. (2020). In their qualitative study, Mamombe et al. (2020) found that even though there was more increase in the level of conceptual understanding in the experimental group, which was taught with an inquiry-based approach, the posttest results of the traditional group also showed an increase in the mean scores. They therefore recommended the incorporation of various teaching methods in science lessons rather than rejecting the traditional methods altogether. They also found that properly planned traditional methods can increase the level of conceptual understanding in learners.

Therefore, the current study puts forward two major findings with regards to the first research question:

- The rejection of the null hypothesis of the study at p=0.00<0.05 and the acceptance of the alternative hypothesis, which states that there is statistically significant difference between the level of conceptual understanding of chemical change in the experimental and control groups, with a higher level of conceptual understanding in the experimental group. Based on these findings, it is concluded that learners taught using the 5E inquiry-based lesson plan will have a higher level of conceptual understanding of chemical change than those taught using traditional teaching methods.

- The rejection of the null hypothesis means that there is no statistical significant difference between the pretest and posttest mean scores in the control group. The null hypothesis was rejected at a p-value, $p=0.000<0.05$. Based on the p-value, the study concludes that there is a significant increase in the posttest mean score in comparison to the pretest in the control group. Therefore, the performance of the learners in chemical change in the posttest of the control group increased significantly more than in the pretest. This means that, even though to a lesser extent than the inquiry-based approach, properly planned traditional teaching methods can increase the level of conceptual understanding in learners.

4.3. ANALYSIS, INTERPRETATION AND DISCUSSION OF QUALITATIVE RESULTS: FOCUS GROUPS INTERVIEWS

The analysis of the pilot study results show that there were interview questions that did not guide learners to the pre-identified themes, were not understandable, and the language of the questions was not put at the learners' level of understanding. Furthermore, the analysis of the pilot study found that in order for all the 14 questions to be answered in one hour, the researcher had to allocate about four minutes per question, which meant that learners had to be rushed. Informed by the analysis of the pilot study, the researcher had to remodel, remove, and replace some questions, in order to ensure that all the questions address the four pre-identified themes or perception indicators, are understandable, and the language is appropriate to the learners. Moreover, the researcher had to reduce the number of questions from 14 to 10, so as to give learners at least six minutes per question to ensure that they had enough time to answer all the questions without being rushed. The outcome was a set of interview questions, which measured all the perception indicators, and were appropriate to the learners (Appendix J).

The semi-structured focus groups interviews were conducted immediately after the administration of the posttest. The interviews were intended to qualitatively support the findings of the pretests and posttests by answering this research question:

II. What are the learners' perceptions on their learning of chemical change under the inquiry-orientated and the traditional-based classroom environment?

The participants in the focus groups were conveniently sampled from those who participated in the pretest and posttest. Sixteen participants from the experimental group and 16 participants from the control group participated in the focus group interviews. Of the 16 participants in each group, eight were in each focus group interview, which means there were four interviews in total, with two from the experimental group and the other two from the control group. The interviews were conducted after school in four sessions of one hour each, where the participants first signed the focus group assent and confidentiality agreement form. The participants were also notified prior to the commencement of the interview session that the interviews would be audio recorded. Furthermore, the participants were made aware that their participation would be voluntary and that there are no rewards for participation. They were also notified that they can revoke their participation without any repercussions. Participants were also advised not to mention names of their school, teachers, or friends, so to maintain the confidentiality of the interviews.

4.3.1 Data analysis from the focus group interviews

The transcribed data from the focus groups interviews was analysed using the five steps as identified by Clarke and Braun (2012) and as quoted in Nembahe (2021) which include:

- Acquaintance and immersion – this step was undertaken during the interviews were the researcher engaged with the participants on the topic to familiarise himself with the topic and extract relevant and rich data from them. This was done by clarity seeking questions, encouraging participation of all participants, and ensuring that participants did not digress.

- Identification of themes – Here, the researcher went through the interview transcripts and the notes and summarised these in such a way that they were aligned with the pre-defined themes from Mensah-Wonky and Adu (2016)'s learners' perception indicators (with additions), which are learners' confidence, teacher support, learners' cohesiveness or cooperation, and knowledge gain. All the identified themes provided in-depth data about the perceptions of the learners on their learning under the inquiry and traditional teaching models. Each theme had two questions that the participants had to answer individually in the focus groups. Two more themes emerged from the coded data, which are: the practical nature of science and teaching style.

- Coding – the researcher carefully went through the transcribed data, word by word, to determine repeated and common words and phrases which he then assigned codes. All the data set was coded to ensure that all the data is analysed and interpreted.

- Explaining – here, further analysis of the data was conducted to identify any emerging themes and to identify and correct mistakes. Two more themes emerged from the coded data which were: the practical nature of science, and teaching style. This increased the number of themes from four to six themes made up of four pre-identified and two emerging.

- Interpretation and verification – in the final step, the different interpretations of the individual codes was consolidated, in order to find common ground in the data, provide explanations, and define concepts.

The researcher read through the transcribed data from the experimental and control groups word by word, and assigned codes to common words and phrases. The identified codes were then linked with a priori themes, which were developed before the current data was examined. According to Maree (2007), a priori themes are developed by the researcher before reading through the current data, usually during literature review, or they are taken from existing studies, which are then used to examine existing theories or expand on them. A priori themes assist the researcher to accelerate the coding process. To minimise the effect of focusing on data that is associated to the identified themes only, the researcher allowed other themes to emerge during the coding process. The whole process resulted in the linking of some codes to the four pre-defined themes, and the codes that were not linked with any a priori themes resulted in the identification of two emerging themes resulting in six themes in total. Qualitative data analysis was first separated into two aspects where the data was analysed based on the pre-defined themes and then emerging themes, after which the whole qualitative process was summarised.

Table 4.17: Pre-defined themes, their explanation and the questions asked in each theme

Theme	Explanation	Questions asked
Theme 1 Learners' confidence	Self-confidence is one of key aspects that ensures effective learning as learners who have good self-confidence will be able to develop their abilities (Abdullah, 2019). Learners who have a good self-confidence are likely to perform well in their studies (Gathage et al, 2021).	• Did you enjoy learning chemical change? Elaborate. • Are you confident enough to share what you learned about chemical change? Elaborate.
Theme 2 Teacher support	Learners who are left to fend for themselves during the process of learning with less teacher support are likely to be demotivated (Khalaf and Zin, 2018). According to Quitaneg-Abaniel (2021) for the process of teaching and learning to yield positive results teachers must not neglect learners to wonder around without purpose but they must question,	• Was there a point during the chemical change lessons that you felt you were no longer following what was being taught? How did you pass through that point? • Do you believe there was enough assistance from your

	facilitate, provide feedback and motivate the learners during the learning process.	teacher during the lessons? Explain.
Theme 3 Learners' cohesiveness/ Cooperation	During the learning process, learners must be able to work well in groups and individually (Khalaf and Zin, 2018). When learners engage in group work, they are able to assist one another and they take up different responsibilities in the group which ensures that they are fully involved in their learning.	• Did you play any role during group discussions in class? Elaborate. • Where you actively participating in class during the chemical change lessons? If not, why?
Theme 4 Knowledge gain	In the context of the study, knowledge gain is indicated by the difference between marks obtained in the pretest and the posttest, and the ability to link chemical change concepts learned in class with things or scenarios they come across in their everyday lives.	• Did you perform the same way in your pretest and posttest? If not, why? • Can you give any examples of applications of chemical change and physical change you may normally come across on daily basis?

Pre-identified themes

4.3.1.1 Theme 1: learners' confidence

I. Experimental group

The general sentiment in the experimental group was that they enjoyed learning chemical change. They mentioned that the experiments were the most interesting part of their lessons. One learner said:

"I enjoyed the lessons because the practicals explained the things that we couldn't understand in our notes."

The learners in this group generally felt that the experiments were interesting, as they made it easy for them to relate what they observed with what is in their notes or textbooks. Experiments are generally described as an integral part of inquiry learning, as Gyamphoh et al. (2020) mention that in an inquiry-orientated science classroom, learners play an active role in their learning, where they conduct investigations, perform experiments, ask questions, and make observations to solve problems, and in so doing, improving their critical thinking skills and their understanding of science concepts. This shows that, while learners were busy engaging in practical activities, they were actually engaging in inquiry learning.

The learners were pleased to share with the researcher what they learned, and they all wanted to say something about chemical and physical changes. The researcher noticed that the level of confidence was very high in the learners as they were eager to share what they learned about chemical change. This observation is in line with the findings of Mupira and Ramnarain (2018) who found that learners in an inquiry classroom environment have self-confidence and are motivated in their learning. Even though the learners correctly mentioned the difference between chemical and physical changes, and also were able to explain what is happening when it came to physical and chemical changes, there were those learners who also incorrectly defined physical and chemical changes. A learner stated that:

"…physical change means that a physical product is formed, and in chemical change products that we cannot see are formed". The definition provided by the learner shows that, despite their excitement and confidence about the lessons, some learners still have misconceptions that were not addressed. The failure of some learners to correctly define and make observations might be due to their over-confidence as Gormally, Brickman and Armstrong (2009) found that learners who were less confident during their learning had better outcomes, while those with high confidence saw reduced outcomes. Learners who are more confident normally do not pay attention to details during their learning, and therefore are likely to make mistakes and subsequently develop misconceptions.

II. Control group

A fraction of the learners in the control group mentioned that they enjoyed the lessons and were able to correctly share what they learned with the group. Some learners indicated that they enjoyed the lessons, and were able to share what they had learned with the group, even though incorrectly so. They incorrectly defined physical and chemical changes respectively as changes that we can see and changes that produces products that we cannot see. In many instances, the learners contradicted themselves, and could not confidently provide an account of what they had learned. Interestingly, some learners in the control group mentioned that they were not able to share with the group what they learned in class, since they have not grasped the concepts well, and did not have enough information. A learner said:

"I cannot share because even though we learned the topic in class, but I could not get time at home to revise what I have learned."

Their inability to share what they have learned may be as a result of lack of motivation caused by insufficient knowledge of the topic. Khalaf and Zin (2018) state that learning under the traditional teaching methods creates a knowledge gap, which results in learners' inability to understand the concepts being studied. The learners felt that it would have been easier for them to grasp the concepts if experiments were incorporated into their lessons. One learner said:

"it is very difficult for me to understand chemical change and physical change without seeing any reactions, I guess it would have been easy for me to understand if we can do experiments, so I can see the contents of the reaction."

The learners' sentiments with regards to experiments supports the notion that Physical Science is a practical subject, and that therefore, it would be impossible to understand it without engaging in any practical activities, whether conducting these or observing them.

4.3.1.2 Theme 2: Teacher support

I. Experimental group

It was noted that a majority of the learners in the experimental group had encountered problems with the balancing of equations, especially when it came to the laws of constant composition and conservation of mass, where they indicated that initially they could not understand how to balance an equation using the law of conservation of mass. When probed further, most of the learners indicated that they eventually managed to understand the balancing of equations by discussing and working together as a group. They also indicated they did not get enough help from the teacher in this regard, as the teacher only suggested textbook page numbers and provided them with extra notes, instead of showing them how to do it. Even though the learners believed that teacher assistance was not enough, one learner mentioned: *"…personally I believe that the less assistance we got from our teacher was good, because we worked on our own in our groups and we managed to get most of the answers correct, even though the teacher was not assisting us."*

In support of the learner's view, Love, Hodge, Carritore and Ernst (2015) posit that an inquiry-orientated classroom environment is learner-centered, and learners are engaged in activities that make sense to them, rather than being provided an easy way to find solutions. They further explain that in such an environment, learners show their utmost participation in classroom activities, while the teacher facilitates the learning process and gives some base information as an introduction to the lesson. The accounts of Love et al. (2005) with regards to an inquiry-based classroom environment show that the experimental group was engaging in inquiry, where the teacher acted as a facilitator and provided learners with the necessary resources for them to engage in inquiry-orientated activities. Even though the learners enjoyed the lessons, some felt that the teacher was not providing them with the necessary scaffolding. This may be as a result of them being used to the traditional teaching methods, and that they may find it difficult to adapt to this 'new' way of learning. A learner in the group mentioned that he believed the lessons would be more interesting if the teacher provided them with more assistance, rather than waiting for them to work out the answers themselves. In alignment with the learner's sentiments in this study, Khalaf and Zin (2018) posit that one of the challenges with the inquiry-based approach is that the reduced teacher involvement of inquiry does not take into account the exhaustion of the working memory of individual learners, which results in a reduced ability to store information.

II. Control group

The learners in the control group found the balancing of equations challenging, with two learners indicating that they also had a challenge, stating the phases of the substances in a chemical equation. Notably, a handful of the learners still experienced a challenge with balancing. This could be attributed to the fact that majority of the learners believe that there was no teacher assistance at all, because the teacher was the one talking, with no time for discussions. One learner claimed that *"the teacher was fast so I as a slow learner couldn't follow what the teacher was teaching about in most instances"*. In contrast, one of the two learners who said they believed there was enough teacher support states that:

"I believe there was enough teacher support because there was a point where I could not understand, I then asked the teacher who clearly explained and I understood."

The general sentiment in the control group with regards to teacher involvement was that there was no support at all from the teacher. The teacher was the one doing the talking throughout, without checking whether learners were following or not. Abdi (2014) describes a traditional-orientated classroom environment as a one-person show, characterised by unilateral and one directional instruction, where the teacher transfers knowledge and his or her theory to the learners, who passively receive.

4.3.1.3 Theme 3: Learners' cohesiveness/cooperation

I. Experimental group

Group discussions took place in the experimental group as the learners mentioned that they were actively participating in the group discussions during the chemical change lessons. The learners went as far as describing their roles during the group discussions, as one of them stated the following*:*

"during our group discussion I was the curious one! [laughing), *always asking other learners, discussing and putting suggestions forward. I always had something to say in our group!"* Another learner mentioned that she was always assisting other learners in their group especially when they forgot other concepts.

The learners seemed to have been active during the group discussions, as they all wanted to mention their roles during the discussions voluntarily. Some stated that they were group leaders, scribes, resourceful members, and researchers. The learners also stated that during the group discussions, they were debating, discussing, and brainstorming together as a group. A majority of the learners indicated that they were active in most of the lessons, asking clarity-seeking questions, or participating in debates during group discussions, or when the teacher was reporting back. One learner highlighted that: *"I was active especially during the practicals, because I was looking forward to the outcome of the reactions."* Another learner mentioned:

"*the group discussions were interesting as the teacher was not interfering with our discussions."*

The learners' sentiments suggest that during the lessons, they were actively involved in their learning and were able to ask one another where they could not understand. Inquiry-based activities such as group discussions and reflections result in meaningful and effective teaching and learning (Mason, 1998). Group discussions are key components of science learning, where Takana (2007) list some advantages of group discussions, which include the fact that they can encourage understanding of a topic being studied during explaining to fellow learners, the approval and disapproval of one's ideas during engagement with other learners, group discussions can also play a major role in fostering scientific skills and humanity in learners. Their ability to clearly explain concepts of chemical change and their willing to share with fellow learners during the interviews suggest that the learners in the experimental group have benefitted greatly from the group discussions.

II. Control group

The learners in the control group mentioned that they were not participating as there were no group discussions, but only copying notes from the chalkboard and listening to the teacher, as he was the only one talking. They further mentioned that they hardly asked any clarity seeking questions, since most of the time, they could not understand the content as the teacher was moving fast. One learner had this to say: *"Sir was too fast for me, so it was difficult to follow him, and to understand some of the concepts."* The learners seemed helpless since they believed the teacher was supposed to provide them with all the necessary resources and had to do all the explanation of the concepts, where, when he moved too fast during the lessons, the learners felt lost. Another learner said*: "I was not following what the teacher was teaching, because I couldn't understand, especially the balancing of equations part."*

The learners' views in the control group suggest that their learning environment was more of a traditionally-orientated learning environment. Khalaf and Zin (2018) describes the traditional-orientated learning environment as a one that is teacher-centred and is characterised by learner activities, which do not support effective group discussions and exploration of the concepts being studied. Such an environment requires of learners to accept information from the teacher as fact (Khalaf and Zin, 2018). The learners' inability to understand chemical change concepts, as one of them mentioned, can be ascribed to the mode of teaching and learning which did not activate the learners' critical thinking ability as a result preventing them from developing conceptual understanding of scientific concepts (Yore, 2001).

4.3.1.4 Theme 4: Knowledge gain

I. Experimental group

The learners in the experimental group said they believe they performed better in the posttest because when they wrote the pretest they had not been taught most of the concepts. One learner said:

" I believe I performed better in the posttest than the pretest because in the pretest I had no idea what was I answering, I did not understand the questions as we haven't studied

the topic as yet. In the posttest I had already learned the chemical change concepts so I was basically flowing, and it did not take me much time to complete the multiple choice questions"

If performance could be based on the opinion of the learners, one would easily say that all the learners in the experimental group achieved better marks in the posttest than in the pretest. One would say the level of confidence in their posttest results indicates the effectiveness of the 5E inquiry-based lesson plan in improving their conceptual understanding of chemical change concepts. This narrative comes about as Widiyatmoko and Shimizu (2018) explain that the inquiry-based approach improves science learners' conceptual understanding, which is necessary for meaningful science learning, and which eventually leads to better outcomes in assessments.

The learners were also able to give correct examples of physical and chemical changes they normally come across on a daily basis. For example, for physical changes they gave examples such as when chocolate melts during a hot day, when liquid water freezes, a cold stove becoming red when lit, etc. For chemical changes, they provided examples such as the conversion of trees into paper, the burning of coal to produce energy and carbon dioxide, dumping site wastes into energy, etc.

Notably, the learners in the experimental group were able to clearly relate the chemical change concepts they learned in class to their everyday lives, and were also able to give correct examples of chemical change, free from misconception. In support of the inquiry-based approach, Widiyatmoko and Shimizu (2018) posit that learners who engage in inquiry-based activities are likely to develop conceptual understanding of the learned concepts, and therefore will not be exposed to misconceptions. Based on the accounts of the learners and the literature, it can be concluded that learners who participate in inquiry-orientated activities will improve their level of conceptual understanding and in the process minimise misconceptions. Furthermore, learners who have developed conceptual understanding in a certain topic are likely to perform better in assessments.

II. Control group

All the learners mentioned that they believed they performed better in the posttest than in the pretest. Their reasons for the improved performance include that they were only guessing in the pretest, but that the information gained during class helped them in the posttest. One learner said:

“I would like to believe that I passed the posttest better than the pretest, because in the pretest I was only guessing the answers, since we were not yet started with the chemical change topic. Meanwhile in the posttest, I was familiar with most of the questions since we have already covered the topic.”

The learner’s view suggests that even learners taught with the traditional teaching methods would have an increase in the level of conceptual understanding and that this would result in a better performance. Furthermore, the learners are of the view that they did not have any knowledge of the topic prior to learning about it. In the posttest, they were now more confident with their performance, because they believe they have gained some knowledge after they were taught.

Moreover, the learners managed to provide correct examples of physical changes they normally come across on a daily basis. Some of the examples include evaporation of water, melting of ice, bending and iron rod, etc. In contrast, learners were not able to provide clear examples of chemical changes, and some even gave examples of physical changes as chemical changes. One can attribute their failure to provide such examples to a lack of practical knowledge, as chemical changes can clearly be observed in chemical reactions during experiments. Moreover, their inability to properly relate the learned knowledge with their everyday lives suggests that their performance in the posttest may not meet their expectations, since they seem to not have developed conceptual understanding of the topic. Lack of conceptual understanding will result on the inability to provide clear explanation and examples related to the learned topic which might lead to the development of misconceptions.

Emerging themes

Table 4.18: Excerpts from data showing how theme 5 and 6 emerged from the data

Themes	Excerpts from data	Themes emerging from data
Theme 5	Experimental group: *"I enjoyed the lessons because the **practicals** explained the things that we couldn't understand in our notes."* *"I was active especially during the **practicals** because I was looking forward to the outcome of the reactions."* Control group: *"it is very difficult for me to understand chemical change and physical change without seeing any reactions, I guess it would have been easy for me to understand **if we can do experiments** so I can see the contents of the reaction."* *"even though there were things I understood while the teacher was teaching such as the definitions of chemical and physical changes, but most of the things were difficult for me to understand such as balancing and the examples, especially those of chemical changes. I believe it would have been easy for us to understand if maybe we **did practicals** so that we can see for ourselves."*	The practical nature of science

Theme 6	<u>Experimental group</u>: "*the group discussions were interesting as the* ***teacher was not interfering*** *with our discussions."* *"… personally I believe that the* ***less assistance we got from our teacher*** *was good because we worked on our own in our groups and we managed to get most of the answers correct even though the teacher was not assisting us."* <u>Control group</u>:*"**the teacher was fast** so I as a slow learner couldn't follow what the teacher was teaching about in most instances"* *"I was not following* ***what the teacher was teaching*** *because I couldn't understand, especially the balancing of equations part".*	Teaching style

4.3.1.5 Theme 5: The practical nature of science

I. Experimental group

The learners in the experimental group believed that their lessons were interesting. They pointed out the experiments they conducted and the group discussions they were engaged in as some of the reasons that made them to enjoy the lessons on chemical and physical changes. One learner said: *"I enjoyed the lessons because the practicals explained the things that we couldn't understand in our notes"*. The learners' perceived experiments as an integral part of their lessons as they were looking forward to the outcomes of the practical experiments. Based on the learners' response one can state that learners taught science using experiments enjoy their lesson and they actively participate in classroom activities. In support of learning science using experiments, Annisa and Rohaeti (2021) found that learners who are taught science using experiments generally enjoy conducting experiments and had many positive reviews about the practical activities they conducted. Annisa and Rohaeti (2021)'s findings supports the views of other researchers that experimental activities are fundamental aspects of inquiry-based learning, as Arends (2012) posits that the inquiry-based approach involves the presentation of the research question, assist with formulation of the hypothesis, encourage learners to conduct experiments to test their hypothesis, and assist learners through literature review to come-up with explanations for their outcomes.

II. Control group

Even though the learners in the control group did not do any practical experiments, but they believed that were experiments to be incorporated into their lessons, they would have understood them. They felt the nature of the topic warranted them to not only memorise but also see what is happening in the reaction mixture. One of the learners even said: *"it is very difficult for me to understand chemical change and physical change without seeing any reactions, I guess it would have been easy for me to understand if we can do experiments so I can see the contents of the reaction."* The learners' sentiments may suggest that the incorporation of practical experiments in science lessons would assist in enhancing the understanding of the concepts. In support of their sentiments, Annisa and Rohaeti (2021) emphasise that for meaningful learning to take place in a science classroom, learners must engage in activities similar to those of practicing scientists, whether this be in the form of questioning, investigation, problem solving or activities they conduct in the laboratory. Moreover, Gyamphoh et al. (2020) propose that in order to improve conceptual understanding of science concepts and critical thinking, learners need to partake in the following activities in their lessons: conducting investigations, performing practical experiments, ask questions and make observations. It is evident that the lack of practical activities in the lessons contributed to the difficulty faced by learners, especially with regards to understanding chemical change concepts, which required them to make observations about the changes that were occurring in the reaction mixture.

4.3.1.6 Theme 6: Teaching style

I. Experimental group

The experimental group perceive their teachers' teaching style to be one that gave them a room to explore their ideas, as they stated that the teacher was not interfering while they were busy with group discussions. One learner also mentioned that she appreciated the fact that their teacher was not giving them too much assistance: *"… personally I believe that the less assistance we got from our teacher was good because we worked on our own in our groups and we managed to get most of the answers correct even though the teacher was not assisting us."* This implies that lessons were learner-centred, where the teacher allowed the learners to explore on their own while providing support and facilitating the learning process. According to Masilo (2018), for science learning to foster conceptual understanding of scientific concepts and promote problem-solving, the teacher must act as an initiator and director of the lessons, where he/she acts as a facilitator and provides learners with the chance to independently engage in scientific enquiry, where they discover concepts and apply scientific knowledge to answer scientific questions and engage in problem-solving. The learners acknowledged that the teacher provided them with the necessary resources, such as printouts, notes, laboratory equipment, worksheets, and textbooks related to chemical change at the beginning of the lessons, which they used during these lessons. They added that during the classroom activities, the teacher was moving around taking observing and taking notes. One learner said: "*We were debating and brainstorming as we were answering questions from the worksheet while the teacher was moving around observing and taking notes without saying a word".* The learners' accounts of events suggest that the teacher perceived his role during the lessons as one who facilitates the lessons by providing scaffolding to the learners and providing them with resources. Furthermore, he carefully observes during the lesson, and takes note of any misconceptions that learners might have so as to address them at a later stage.

II. Control group

The learners in the control group indicated that their teacher was writing notes on the chalkboard in most instances, while also verbally answering their questions. The learners said that in most cases, they were lost during the lessons, as the teacher was moving fast so most of them were not following. One learner had this to say: *“Sir was too fast for me, so it was difficult to follow him, and to understand some of the concepts.”* Based on the learners views one can say that the teacher was using traditional teaching methods which Abdi (2014) describe as teacher-centred methods which are one directional and direct. Moreover, Abdi (2014) adds that such a teacher seeks to ‘pour’ knowledge into the passive learners as he/she believes they occupy the only position that is knowledgeable. The learners in that classroom have a limited space to explore and critically engage the content. The learners in the control group seemed to have difficulties with understanding concepts related to chemical and physical change especially the balancing of chemical equations, describing chemical changes and relating chemical changes to their everyday lives. A learner asserted that: *“even though there were things I understood while the teacher was teaching such as the definitions of chemical and physical changes, but most of the things were difficult for me to understand such as balancing and the examples, especially those of chemical changes. I believe it would have easy for us to understand if maybe we did practicals so that we can see for ourselves”.* The learners concerns might be due to the teaching method utilised in the classroom as Mensah-Wonky and Adu (2016) claim that the traditional teaching methods are not effective in teaching mathematics and science, as they do not promote critical thinking and problem-solving, of which constitute necessary skills for the development of conceptual understanding of core scientific and mathematics concepts.

4.3.2. Discussion of the major qualitative findings

4.3.2.1. Perceptions of learners on their learning environments

In a nutshell, the findings of the focus group interviews shows that learners taught in the inquiry-orientated classroom environment perceive their learning to one that encourages active learning, promotes group discussions, has less teacher involvement, and improved knowledge gain.

It is worthwhile to note that the learners in both the experimental and control groups believe that they performed better in the posttest than the pretest, and the reasons for their better performance in the posttest include that they wrote the pretest prior their learning of the chemical change topic. One learner asserted: *"I would like to believe that I passed the posttest better than the pretest because in the pretest I was only guessing the answers since we were not yet started with the chemical change topic. Meanwhile in the posttest I was familiar with most of the questions since we have already covered the topic."* The fact that the learners in both groups acknowledge that their knowledge of chemical change was meager before they were taught may suggest that their level of understanding of the topic was the same. This suggests that both groups departed from the same point in terms of their conceptual understanding of chemical change. Such findings assist in directly linking the learners' views about their lessons to the teaching approach under which they were learning.

Learners taught chemical change under the traditional teaching methods perceive the approach as teacher-centred, as one that does not encourage practical experiments, and rote learning, and therefore does not assist them to understand the topic. Others even suggested that it was possible that if they were learning the topic using experiments they would understand it better. The learners' views are similar to those of several studies (Abdi, 2014; Khalaf and Zin, 2018; Masilo, 2018; Simsek and Kabapinar, 2010), which describe the traditional teaching methods as teacher-centred, passive, not able to encourage active participation, and failing to promote critical thinking and conceptual understanding. Moreover, it was found that learners in the control group did not understand key concepts of the chemical change topic, such as the balancing of equations, laws in chemical change such as the law of constant composition, and linking content of chemical change to everyday life events or setups. One of the reasons of their poor understanding of the topic is the fact that the topic had practical aspects, which required learners to observe various chemical reactions before they were able to deal with questions on the topic. In support of the analysis, one learner said: "*I believe it would have been easy for us to understand if maybe we did practicals so that we can see for ourselves."* Furthermore, they indicated that the lessons were a 'one man show', where the teacher was doing everything, with less interaction taking place in class. This led learners to feel helpless, as they often went home with many unanswered questions, and could not move beyond what they were taught.

In theme 1, all the learners in the experimental group enjoyed their lessons and they were ready to share what they learned with their fellow learners without hesitation. Gathage et al. (2021) similarly concluded that learners in an inquiry-based learning environment have a higher self-esteem and self-image and believe that they have what it takes to learn. The learners in the experimental group played various roles during class group discussions and they mentioned that they enjoyed working in groups, because they were able to discover things themselves, and were able to ask their peers where they did not understand. In agreement with this findings, Primada et al. (2018) found that teaching learners using inquiry methods gave learners the opportunity to research, analyse, and participate actively in classroom activities. Furthermore, learners taught with inquiry and traditional methods all felt that they were not supported enough by their teachers. Those in the experimental group felt empowered by the limited role of the teacher, as they mentioned that they were able to work independently and were forced to read more and discuss more with their peers than they normally would do in order to get the expected answers. The findings are in line with deliberations by Kamal and Suyanta (2021) that inquiry approaches encourage independent learning, where learners work in groups or alone, which makes them more active in their learning process and encourages higher order thinking in contrast to learning under traditional methods which are teacher-centred and learners are expected to read and memorise information without encouraging research and analysis.

The study also found that learning under inquiry-based (experimental group) and traditional-based (control group) learning environments improves performance in relation to the concepts learned, but learners taught with inquiry approaches perform better than their counterparts. This conclusion was reached based on the accounts of the learners regarding their views about their performance in the pretest and posttest. The learners in both groups indicated that they believed they performed better in the posttest than in the pretest. Their accounts imply that, despite the teaching method used to teach them chemical change, they performed better after being taught than before the lessons. These findings are important, as several studies (Abdi, 2014; Annisa and Rohaeti, 2021; Feyzioglu and Demirci, 2021; Simsek and Kabapinar, 2010; Primada et al, 2018) conducted on inquiry-based approaches and the traditional teaching approaches indicate that learners taught scientific concepts using traditional teaching methods did not show any noticeable improvement in their level of conceptual understanding. Despite learners from both groups indicating that they performed better in their posttest, it is worthwhile to note that the learners in the experimental group managed to correctly link the concepts of chemical change that they learned in class with the scenarios or objects they normally come across in their daily lives, meanwhile their counterparts only got examples of physical changes correct without linking them with their daily lives. This indicates that learners in the experimental group gained more knowledge than those in the control group, as Sari and Haji (2021) state that a learner who has developed a conceptual understanding of a certain concept ought to be able to explain the concept in his own words and apply it in real-life situations. Mamombe et al. (2020) also found that both inquiry-based methods and properly planned traditional approaches improve the performance of learners, but the performance of those taught with inquiry methods is better than those taught with the traditional methods.

4.4. TRIANGULATION OF RESEARCH FINDINGS

The overall mean scores in the pretest of both the experimental and control groups were found to be 33.16 and 34.78, respectively, meanwhile the standard deviation in both groups was found to be 11.60 and 11.03, respectively. These results, together with the p-value of the independent sample t-test on the pretest mean scores of both groups ($p=0.226>0.05$), suggest that both groups were at the same level of conceptual understanding before the administration of the intervention to the experimental group. This finding suggests that both groups departed from the same point, in terms of knowledge of chemical change, where any observed changes in the performance of the experimental group were ascribed to the 5E inquiry-based lesson, which was the intervention. In support of these findings, a qualitative analysis found that the learners in both the experimental and control groups believed that they performed better in the posttest than in the pretest, noting that this was due to the pretest being written before they were taught. Moreover, they mentioned that in the pretest, they were just guessing answers, since they were not familiar with most of the concepts. The researcher concluded that learners in both groups were at the same level of conceptual understanding of chemical change before they were taught, noting that they did not know many concepts of chemical change prior to the intervention.

The study also found that learners in both the experimental and control groups significantly improved their conceptual understanding of chemical change concepts in the posttest, resulting in the retention of the null hypothesis that there is no statistical significant difference between the mean scores of the pretest and posttest in both groups. This conclusion was reached based on the paired sample t-tests on the pretest and posttest mean scores of both the experimental and control groups, where the p-values were found to be $p=0.000<0.05$ in both mean pairs. The results indicate that learners in both groups obtained significant scores in the posttest rather than in the pretest, which means that both the inquiry-based approach and the traditional teaching methods significantly improved the performance in chemical change in the posttest rather than in the pretest. These findings are of interest as several studies on inquiry-approaches and traditional approaches found no significant difference between the pretest and posttest mean scores of the control group, except in a qualitative study conducted by Mamombe et al. (2020) on the influence of inquiry-based approach on conceptual understanding of the particulate nature of matter, where they found that, even though the learners taught using inquiry improved their level of conceptual understanding more than did their counterparts, there was also an improvement observed in the learners taught using the traditional teaching methods. In the current study, learners in both the experimental and control groups mentioned that they believe they performed better in the posttest, because the posttest was written after they had studied the topic. They further mentioned that they believed they did well in the posttest because they wrote the posttest after being taught the topic, where they knew many concepts asked in the posttest. Their sentiments suggest that learners in both groups believed that they did well in the posttest due to the teaching approach that assisted them in improving their knowledge of chemical change concepts.

The independent sample t-test showed that there was significant difference ($p=0.000<0.05$) in the level of conceptual understanding between the learners taught using the inquiry-based approach and those taught with the traditional approach. This means that the level of conceptual understanding of chemical change concepts in the experimental group increased more than it did in the traditional group. Despite an increase in the level of conceptual understanding in the experimental group, the mean scores and the N-gain scores in the posttests were higher than those in the pretests in both the experimental and control groups. An increase in the mean and N-gain scores in both groups indicated that learners in both groups experienced an improved level of conceptual understanding in the posttests. In summary, the study found that both inquiry-based approach and traditional approach increases the performance of the learners in chemical change, with the inquiry-based approach having a greater increase than the traditional approach. This finding is also supported by the focus group interviews. The analysis of the focus groups interviews concluded that learners in both the inquiry group and the traditional group performed better in their posttests, due to the fact that all the learners in both groups indicated that they did better in the posttest than in the pretest, because when they wrote the posttest, they had more information about chemical changes than in the pretest. Nevertheless, the learners in the experimental group gained more knowledge than their counterparts in the control group, due to the fact that those in the experimental group were able to correctly link what they had learnt in class with their everyday life. This means that the experimental group performed better than the control group, and had an increased level of conceptual understanding of chemical change concepts than did their peers in the control group. For this reason, the study concludes that the 5E inquiry-based approach increases the level of conceptual understanding of chemical change concepts more than does the traditional teaching approach. The higher increase in the level of conceptual understanding in learners taught under the inquiry-based approach environment results from the fact that they perceive their learning environment as one that encourages active learning, promotes group discussions, has less teacher involvement, and improves their knowledge gain.

The qualitative and quantitative findings of the study are aligned with the constructivist theory, as the founding theory of the study. Qualitative data found that learners taught with the 5E inquiry-based lesson plan perceive their learning environment to encourage active participation in the learning process, whereby learners work on their own and in groups to solve problems and answer scientific questions with little assistance from the teacher. In support of these findings, Hein (1991) and Williams (2017) describe constructivist theory as a theory of learning that promotes learner-centred teaching and learning, acknowledges prior knowledge, learners' interaction, and physical and mind activities, which, as according to Gyamphoh et al. (2020), are all features of inquiry-based approach and are important in science learning. In the current study, it was found that the learners taught using the inquiry-based lesson plan managed to build their knowledge of chemical change more than their counterparts, who were taught with the traditional teaching methods, and it is for that reason that they improved their level of conceptual understanding of chemical change more than did their counterparts. These is in line with Dewey's constructivist's progressive education and learning theory, where it is emphasised that learners learn by building their own knowledge through 'minds-on' and hands-on activities in which they partake independently of the teacher, whether in groups or individually. In conclusion, the findings supports the constructivist theory of learning, and prove that the 5E inquiry-based lesson plan as the intervention in the study was designed in line with the constructivist theory of learning.

4.5. CONCLUSION

This chapter, analysed, interpreted, and discussed the findings of the study. The chapter examine how quantitative and qualitative data collected from 142 Grade 10 Physical Sciences learners using pretest-posttest and focus group interviews was used to determine the effects of inquiry-based approach on the conceptual understanding of chemical change. From the analysis, interpretation, and discussion of the findings, it was determined that learners taught using the inquiry based approach have a higher level of conceptual understanding than their counterparts taught with traditional teaching approach, and that they perceive their learning environment to be one that allows active learning, encourages group and individual learning, and promotes knowledge gain. In the next chapter, the study findings, conclusions, and recommendations will be presented.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1. INTRODUCTION

The chapter presents the summary of the findings of the study, draws conclusions based on the findings, and puts forward recommendations for the DBE, science teachers, and future studies, based on the findings of the study. The purpose of the study was to determine the effects of an inquiry-based approach on Grade 10 learners' conceptual understanding of chemical change topic in Physical Sciences by using pretest-posttest and focus group interviews to answer the following research questions:

I. *What are the effects of an inquiry-based teaching approach on Grade 10 learners' conceptual understanding of chemical change concepts in Physical Sciences in comparison with the traditional teaching approach?*

The null hypothesis of the first research question was:
H0 = There is no statistically significant difference in conceptual understanding of chemical change between Grade 10 learners taught with an inquiry-based teaching approach and those taught with the traditional teaching approach in the posttest results.

The alternative hypothesis for the null hypothesis was:
HA= There is statistically significant difference in conceptual understanding of chemical change in Grade 10 learners taught with an inquiry-based teaching approach and those taught with the traditional teaching approach in the posttest results.

The null hypothesis was tested at significance level, $\alpha = 0.05$

II. *What are the learners' perceptions on their learning of chemical change under the inquiry-based approach and the traditional based approach classroom environment?*

In this study, the independent variables were the inquiry-based teaching approach, and the traditional teaching approach, where the dependent variable was conceptual understanding.

5.2. SUMMARY OF THE STUDY

Despite the various efforts of the government to improve poor performance in Physical Sciences and Mathematics, South African learners still perform poorly in those subjects. Studies conducted in South Africa (Bidi, 2018; Mamombe et al., 2020; Penn et al., 2021) suggest that one of the factors leading to poor performance in Physical Sciences is the teaching strategies that science teachers utilise in their lessons. Many science teachers are said to be still using traditional teaching strategies, despite the positive effects of inquiry-based approaches to science teaching. Chemistry was found to be the most difficult part of Physical Sciences, with Chemical Change described as the most challenging topic in Chemistry, which also contributes to the high failure rate in the subject. The aim of the study was to determine the effects of an inquiry-based teaching approach on Grade 10 learners' conceptual understanding of chemical change in Physical Sciences, with the view of improving their performance in the subject.

The literature reviewed in Chapter 1 and Chapter 2 discovered that the implementation of inquiry-based approaches in science classrooms positively affects teaching and learning, learners' self-concept and motivation, conceptual, and academic achievement. It further discovered that, despite the many advantages of inquiry-based approaches, such as the 3E, 5E, and 7E learning cycle models, many Science teachers have not yet applied these approaches in their lessons. They cite large classroom sizes, lack of resources, time constraints, and crammed curricula as some of the reasons that hinder the implementation of inquiry-based approaches in their classrooms. Some critics of inquiry believe that some forms of inquiry, such as open inquiry, where learners formulate their own questions, conducts research, analyse data, and provide answers to their own research questions without assistance from the teacher, mostly leave learners helpless without guidance, and as a result, learners become demotivated. Critics state that these forms of inquiry, mostly labelled as 'true inquiry' in most cases, have a negative effect on learner achievement. Studies conducted in South Africa and elsewhere around the world show increases in the level of learners' conceptual understanding of scientific concepts. Even though such studies have been conducted in South Africa (Bidi, 2018; Mamombe et al., 2020; Penn et al., 2021), none (as far as I know) have focused on Grade 10, which is described as one of the most important Grades in South Africa as it prepares learners for the transition from the GET phase to the FET phase. The current study focused on determining the effect of inquiry-based approach on conceptual understanding of chemical change on Grade 10 learners from township and semi-township schools.

Chapter 3 and Chapter 4 respectively focus on the methodology and data analysis of the study. The study took a quantitative and qualitative approach, with a quasi-experimental design involving pretest-posttest nonequivalent groups and interviews. Using purposive sampling, 142 Grade 10 Physical Sciences learners from four schools around Mgwenya and Sikhulile Circuits under the Ehlanzeni School District in Mpumalanga Province participated in the pretest and posttests, which were conducted in order to answer the first research question, by testing the null hypothesis of the study:

H0 = There is no statistically significant difference in conceptual understanding of chemical change between Grade 10 learners taught with an inquiry-based teaching approach, and those taught with the traditional teaching approach in the posttest results.

Of the 142 participants, 69 were from two schools, which were randomly selected into the control group, which was taught using the traditional teaching approach, meanwhile the 73 where from the other two schools, which were randomly sampled into the experimental group, which was taught using the 5E inquiry-based lesson plan. The pretest was written on the first day of the data collection period, while the posttest was written on the last day, which was two weeks later. Both the pretest and posttest had 10 similar MCQ questions of two marks each. The 10 questions were grouped in pairs according to the five conceptual understandings, as identified by Makhrus et al. (2021), which respectively include interpretation, comparison, explanation, inference, and classification. The tests were collected and marked by the researcher. Quantitative data was generated from the tests marks and were summarised into percentages, mean scores, standard deviation scores, and the N-gain scores. The posttest mean scores of both the experimental group and the control group both showed an increase when compared with those of the pretests. Three of the five conceptual understanding indicators showed a medium N-gain score, with only ‘compare’ and ‘classify’ showing a low N-gain score in the experimental group. Moreover, all the indicators in the control group showed a low N-gain score. The null hypothesis of the study was rejected on a p value of $p=0.000<0.05$, and the alternative hypothesis was accepted. The independently sampled t-test results showed that there was a significant difference between the Grade 10 learners’ conceptual understanding of chemical changes topic into the experimental and the control groups, in favour of the experimental group. The paired samples t-test results showed a significance difference between the pretest and posttest results of the experimental and control groups, with a significant difference observed in the experimental group.

The focus group interviews were conducted in the third week in four sessions, after the tests. Thirty-two participants from the 142 were conveniently sampled to participate in the focus group interviews, 16 were from the experimental group, while the other 16 were from the control group. The findings of the focus group interviews showed that learners taught under the inquiry-orientated classroom environment perceived their learning to encourage active learning, promote group discussions, have less teacher involvement, and improve their knowledge gain.

5.3. SUMMARY ON THE RESEARCH FINDINGS

The section presents the major findings of the study with regards to the research questions and objectives of the study as discussed in Chapter 4:

5.3.1. The effects of inquiry-based approach on learners’ conceptual understanding

The study puts forward that the 5E inquiry-based teaching approach increases the level of conceptual understanding. This means that lessons planned and conducted using the 5E inquiry-based approach will improve the learners’ understanding of scientific concepts, and therefore increasing the performance of the learners in the subject. The findings are in line with the recent studies about the effects of inquiry-based approaches on conceptual understanding (Annisa and Rohaeti, 2021; Bidi, 2018; Feyzioglu and Demirci, 2021; Hidayat and Iksan, 2021; Kamal and Suyanta, 2021; Mamombe et al., 2020).

The study also submits that, even though the inquiry-based approach shows a higher increase in the level of conceptual understanding in science learners, traditional methods are also shown to be effective in increasing the performance of learners in science. This is in contrast with most of the literature reviewed in this study, which labels traditional methods as outdated, passive, and ineffective in science teaching. Many studies note these methods are teacher-centred, where learners are passive. Studies conducted by Abdi, 2014; Annisa and Rohaeti, 2021; Feyzioglu and Demirci, 2021; Hidayat and Iksan (2021); Kamal and Suyanta (2021); Mensah-Wonky and Adu (2016); Simsek and Kabapinar, 2010; and Primada et al. (2018) showed that inquiry-based approaches were effective in increasing the level of conceptual understanding. The paired sample t-test conducted on the control group, which was taught using the traditional teaching methods in a study by Mensah-Wonky and Adu (2016) about the effect of inquiry-based approach on conceptual understanding, which found that there was no significant difference between the pretest and posttest mean scores. On the other hand, Mamombe et al. (2021) found that, even though there was a greater increase in the level of conceptual understanding in the inquiry group, the posttest mean score of the control group also showed an increase. They, therefore recommended the incorporation of various teaching methods in science lessons, rather than rejecting the traditional teaching methods altogether.

5.3.2. Perception of learners on their learning of chemical change under the inquiry-based approach and traditional-based approach classroom environments

The study found that learners learning under the inquiry-based approach perceive their learning to be active, support group discussion, having teacher involvement, and promoting knowledge gain. Learning under the inquiry-based approach environment encouraged active participation of all learners in their learning as they conduct experiments, and research and conduct data analysis in order to answer research questions they formulated themselves. Moreover, group discussions promote the participation of all learners, as learners engage in debates, brainstorm, and present their findings. Furthermore, group discussions encourage even those learners with a low self-esteem to participate, as they would normally find it easier to ask their peers where they didn't understand, rather than the teacher. Learners taught using inquiry believe that less teacher involvement encourages them to discover things themselves, rather than to be spoon fed. They mentioned that they enjoy working individually and in their groups to analyse information and make discoveries themselves. Moreover, learning under the inquiry-based approach promotes knowledge gain, and provides learners with those skills necessary to apply the learned knowledge to environments in their actual daily lives. The findings are in agreement with many studies reviewed. For example Gyamphoh et al. (2020) posit that, in an inquiry-orientated Science classroom, learners play an active role in their learning where they conduct investigations, perform experiments, ask questions and make observations to solve problems, and in so doing, improve their critical thinking skills and their understanding of science concepts.

5.4. RECOMMENDATIONS

5.4.1. Recommendations to the Department of Basic Education

- Curriculum developers should update the Physical Sciences curriculum to make it possible for teachers to incorporate inquiry-based teaching approaches together with other forms of teaching such as properly planned traditional teaching strategies.
- Curriculum developers should trim the Physical Sciences syllabus so that teachers are given more time to implement or incorporate inquiry-based approaches in their lessons.
- Curriculum implementers or curriculum developers should create common lesson plans for Physical Sciences teachers, which incorporate inquiry-based teaching approaches together with traditional teaching approaches, and make these available to schools.
- Curriculum implementers should consistently conduct workshops on inquiry-based approaches and other teaching strategies to equip teachers with the necessary skills to develop lesson plans that incorporate different teaching strategies.

5.4.2. Recommendations for Physical Sciences teachers

- Physical Sciences teachers should implement forms of inquiry that are suitable to their classroom conditions. For example, in overcrowded classrooms, teachers can use confirmation or structured inquiry, which is less time-consuming and less disruptive.
- Physical Sciences teachers should use different teaching strategies for different lessons, depending on the lesson aims and goals, instead of only using the traditional teaching approach, which may not be effective in other lessons.
- In cases where there are not enough laboratory apparatus, Physical Sciences teachers should use demonstrations and inquiry-based worksheets to foster inquiry-based lessons in their classes.

5.4.3. Recommendations for future research

- Similar research can be conducted in rural schools to determine the effect of inquiry-based approaches on rural schools' learners' conceptual understanding.
- Similar research can be conducted to investigate the effects of other forms of inquiry such as the 7E or 9E inquiry cycle models on learners' conceptual understanding.
- Research on the effect of inquiry on problem-solving skills and critical thinking in Grade 10 Physical Sciences learners from township and semi-township schools since they are described as key in the development of conceptual understanding.
- Research can be conducted on similar topics with a longer data collection period.

5.5. SIGNIFICANCE OF THE STUDY

The continued poor performance of learners in Physical Sciences despite the many interventions that the government has introduced shows that more research based on different teaching strategies and learning approaches used in science learning still need to be conducted in order to determine a strategy or strategies that can work in the South African context so as to improve the learners' performance in the subject. Furthermore, more studies still need to be done on the effects of inquiry-based approaches on Grade

10 learners' conceptual understanding in order to supplement the number of studies which have already been conducted, since Grade 10 is described as one of the most important grades in South Africa, as it caters to learners who are doing Physical Sciences for the first time, and are transitioning from the GET to the FET phase. Furthermore, most of the studies about the effects of inquiry on conceptual understanding were conducted outside South Africa, in schools with different social backgrounds, than in South Africa, where most schools are situated in semi-townships and townships. The findings of the study thus adds to the South African perspective in the global body of knowledge.

5.6. LIMITATIONS OF THE STUDY

Due to time constraints, the data collection period only took three weeks, where two weeks were dedicated to collecting quantitative data, while the one week was dedicated to focus group interviews. The duration of the study could have been longer, so as to better determine the effects of inquiry on conceptual understanding. Moreover, the data collection period did not cover all the topics under chemical changes. The shorter period of data collection may have affected the validity of the study.

The participants of the focus group interviews were conveniently sampled, based on who wanted to be interviewed, and who would be available for one hour after school. This means that other learners, who might have provided in-depth information about the topic, could not participate, because they may have been hesitant, or may have lived far from the school, so they decided not to participate. Therefore, the interview findings might not give the true reflection of the participants' opinion.

Even though the researcher took great care when analysing the data, the researcher does not dispute the fact that other factors may have increased the level of conceptual understanding in the experimental group, or caused a decrease in the level of conceptual understanding in the control group. These factors include some teachers not honoring their class periods, teachers not adhering to the ATP's time allocation, and the content knowledge of the teacher.

5.7. CONCLUSION

Even though the inquiry-based approach is found to increase the level of conceptual understanding in science learners more than the traditional teaching approach, we cannot discard traditional teaching methods, as these also show to increase the performance of learners in Science. Properly planned traditional methods can be used together with inquiry methods, especially when it is not possible to use inquiry methods alone. The aims of every lesson ought to be the determining factor on which approach to use in order to ensure that the objectives of the lessons are met, but nevertheless, in all their lessons, teachers must ensure that there is a certain level of inquiry. The study also affirms the effectiveness of inquiry-based approach in increasing the level of conceptual understanding in science learners, especially those in township or semi-township schools which are normally characterised by overcrowded classes, poor basic infrastructure and a lack of laboratories, and lack of basic study materials such as textbooks. The findings of this study will go a long way in affirming amongst teachers in township and semi-township schools that it is possible to successfully implement inquiry-based approaches even in classroom environments characterised by overcrowding, and lack of variety teaching aids.

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APPENDIX A: APPROVAL LETTER FROM EHLANZENI DISTRICT

education
MPUMALANGA PROVINCE
REPUBLIC OF SOUTH AFRICA

Ikhamanga Building, Government Boulevard, Riverside Park, Mpumalanga Province
Private Bag X11341, Mbombela, 1200
Tel: 013 766 5552/5115, Toll Free Line: 0800 203 116

Litiko le Temfundvo, Umnyango we Fundo | Departement van Onderwys | Ndzawulo ya Dyondzo

Enq : Magambe SS Mahlalela
Contact: 079 525 7975 (magambe.mahlalela@gmail.com)

TO : **THE CIRCUIT MANAGERS – MGWENYA AND SIKHULILE**
: **PRINCIPALS OF SCHOOLS – MGWENYA AND SIKHULILE**

CC : **THE RESEARCHER - MR NKOSINATHI W. NKOSI**

FROM : **THE DISTRICT DIRECTOR**

DATE : **31 MARCH 2022**

SUBJECT : PERMISSION FOR MR NW NKOSI TO DO RESEARCH

1. The above matter refers.
2. Mr NW Nkosi is one of our local teachers and has written to the Department, asking for permission to do research under the title:

   THE EFFECTS OF AN INQUIRY-BASED TEACHING APPROACH ON GRADE 10 LEARNERS' CONCEPTUAL UNDERSTANDING OF CHEMICAL CHANGES IN PHYSICAL SCIENCES".

3. According to the request, the participating schools, circuits and district in the research will have access to the results of the research.
4. The Department notes that the research is in line with its educational goals, for example improving learner performance in Maths and Science.
5. Permission is accordingly granted to Mr Nkosi to start with the research.
6. Circuit Managers and school principals are requested to support the study.
7. Finally, the Department looks forward to the results of the research.

Thank you

Mahlalela
District Director

31/03/2022
Date

APPENDIX B: REQUEST FOR PERMISSION TO CONDUCT RESEARCH AT EHLANZENI DISTRICT

RESEARCH TITLE: THE EFFECTS OF AN INQUIRY-BASED TEACHING APPROACH ON THE GRADE 10 LEARNERS' CONCEPTUAL UNDERSTANDING OF CHEMICAL CHANGE IN PHYSICAL SCIENCES.

Date: March 2022

The District Director
Ehlanzeni District
Mpumalanga Department of Education
Telephone: 013 766 0303 and email address.....................

Dear Sir/Madam

I, Nkosinathi Willy Nkosi am doing research under supervision of Prof A.T Motlhabane, a Professor in the Department of Science and Technology Education towards an M Ed degree at the University of South Africa. I am requesting for permission to conduct a study at Ehlanzeni School District titled: THE EFFECTS OF AN INQUIRY-BASED TEACHING APPROACH ON THE GRADE 10 LEARNERS' CONCEPTUAL UNDERSTANDING OF CHEMICAL CHANGE IN PHYSICAL SCIENCES.

The aim of the study is to determine the effects of an inquiry-based teaching approach on the Grade 10 learners' conceptual understanding of chemical change in Physical Science with the view of improving their performance in the subject.

The Ehlanzeni School district has been selected because it consists of schools from different quintile levels which will allow the research to gather data that will give a true reflection of the challenge faced by learners in Physical Science, and also because it is closer to the researcher.

The study will entail gathering quantitative and qualitative data from approximately 160 Physical Science Grade 10 learners in four different high schools through pretest and posttest, and semi structured focus group interviews respectively.

According to the 2021 National Senior Certificate Diagnostic Report, part 1 for content subjects, learners still struggle to answer problems that requires them to possess problem-solving skills, be analytical and evaluative. Therefore, the study is aimed at determining the effect of inquiry-based approach on learners' conceptual understanding which is described as key in enhancing problem solving skills in learners. Moreover, the study is expected to provide answers on whether the implementation of inquiry-based teaching approach improves science learners' conceptual understanding which will eventually improve their performance in the subject.

There is no emotional or physical harm anticipated to the participants since the study does not focus on learners' physical activity or learners' personal issues. Since the study is to be conducted in the midst of a global pandemic, I as the researcher will ensure that all the participants adhere to the COVID-19 guidelines during the research, such as recording of their temperatures, wearing of face masks all the time, washing of hands, sanitizing and social distancing.

There will be no reimbursement or any incentives for participation in the research.

Feedback procedure will entail making the summary of the results available to the participating school's libraries where they will be easily accessible to everyone.

Yours sincerely

____________________________ NKOSI NW (RESEARCHER)

APPENDIX C: REQUEST FOR PERMISSION TO CONDUCT RESEARCH AT MGWENYA CIRCUIT

RESEARCH TITLE: THE EFFECTS OF AN INQUIRY-BASED TEACHING APPROACH ON THE GRADE 10 LEARNERS' CONCEPTUAL UNDERSTANDING OF CHEMICAL CHANGE IN PHYSICAL SCIENCES.

Date: March 2022

The Circuit Manager
Mgwenya Circuit
Mpumalanga Department of Education
Tel:.................................... and email address..................................

Dear Sir/Madam

I, Nkosinathi Willy Nkosi am doing research under supervision of Prof A.T Motlhabane, a Professor in the Department of Science and Technology Education towards an M Ed degree at the University of South Africa. I am requesting for permission to conduct a study in Ehlanzeni District titled: THE EFFECTS OF AN INQUIRY-BASED TEACHING APPROACH ON THE GRADE 10 LEARNERS' CONCEPTUAL UNDERSTANDING OF CHEMICAL CHANGE IN PHYSICAL SCIENCES.

The aim of the study is to determine the effects of an inquiry-based teaching approach on the Grade 10 learners' conceptual understanding of chemical change in Physical Science with the view of improving their performance in the subject.

The Ehlanzeni School district has been selected because it consists of schools from different quintile levels which will allow the research to gather data that will give a true reflection of the challenge faced by learners in Physical Science, and also because it is closer to the researcher.

The study will entail gathering quantitative and qualitative data from approximately 160 Physical Science Grade 10 learners in four different high schools through pretest and posttest, and semi structured focus group interviews respectively.

According to the 2021 National Senior Certificate Diagnostic Report, part 1 for content subjects, learners still struggle to answer problems that requires them to possess problem-solving skills, be analytical and evaluative. Therefore, the study is aimed at determining the effect of inquiry-based approach on learners' conceptual understanding which is described as key in enhancing problem solving skills in learners. Moreover, the study is expected to provide answers on whether the implementation of inquiry-based teaching approach improves science learners' conceptual understanding which will eventually improve their performance in the subject.

There is no emotional or physical harm anticipated to the participants since the study does not focus on learners' physical activity or learners' personal issues. Since the study is to be conducted in the midst of a global pandemic, I as the researcher will ensure that all the participants adhere to the COVID-19 guidelines during the research, such as recording of their temperatures, wearing of face masks all the time, washing of hands, sanitizing and social distancing.

There will be no reimbursement or any incentives for participation in the research.

Feedback procedure will entail making the summary of the results available to the participating school's libraries where they will be easily accessible to everyone.

Yours sincerely

_____________________________ NKOSI NW (RESEARCHER)

APPENDIX D: REQUEST FOR PERMISSION TO CONDUCT RESEARCH FROM SCHOOL PRINCIPAL

RESEARCH TITLE: THE EFFECTS OF AN INQUIRY-BASED TEACHING APPROACH ON THE GRADE 10 LEARNERS' CONCEPTUAL UNDERSTANDING OF CHEMICAL CHANGE IN PHYSICAL SCIENCES.

Date: March 2022

The Principal
……………………….Secondary School

Tel:................................ Email:………………………….

Dear Sir/Madam

I, Nkosinathi Willy Nkosi am doing research under supervision of Prof A.T Motlhabane, a Professor in the Department of Science and Technology Education towards an M Ed degree at the University of South Africa. I am requesting for permission to conduct a study in Ehlanzeni District titled: THE EFFECTS OF AN INQUIRY-BASED TEACHING APPROACH ON THE GRADE 10 LEARNERS' CONCEPTUAL UNDERSTANDING OF CHEMICAL CHANGE IN PHYSICAL SCIENCES.

The aim of the study is to determine the effects of an inquiry-based teaching approach on Grade 10 learners' understanding of chemical change in Physical Science with the view of improving their performance in the subject.

The Ehlanzeni School district has been selected because it consists of schools from different quintile levels which will allow the research to gather data that will give a true reflection of the challenge faced by learners in Physical Science, and also because it is closer to the researcher.

The study will entail gathering quantitative and qualitative data from approximately 160 Physical Science Grade 10 learners in four different high schools through pretest and posttest, and semi structured focus group interviews respectively.

According to the 2021 National Senior Certificate Diagnostic Report, part 1 for content subjects, learners still struggle to answer problems that requires them to possess problem-solving skills, be analytical and evaluative. Therefore, the study is aimed at determining the effect of inquiry-based approach on learners' conceptual understanding which is described as key in enhancing problem solving skills in learners. Moreover, the study is expected to provide answers on whether the implementation of inquiry-based teaching approach improves science learners' conceptual understanding which will eventually improve their performance in the subject.

There is no emotional or physical harm anticipated to the participants since the study does not focus on learners' physical activity or learners' personal issues. Since the study is to be conducted in the midst of a global pandemic, I as the researcher will ensure that all the participants adhere to the COVID-19 guidelines during the research, such as recording of their temperatures, wearing of face masks all the time, washing of hands, sanitizing and social distancing.

There will be no reimbursement or any incentives for participation in the research.

Feedback procedure will entail making the summary of the results available to the participating school's libraries where they will be easily accessible to everyone.

Yours sincerely

____________________________ NKOSI NW (RESEARCHER)

APPENDIX E: REQUEST FOR PERMISSION TO CONDUCT RESEARCH FROM GRADE 10 SCIENCE EDUCATOR

RESEARCH TITLE: THE EFFECTS OF AN INQUIRY-BASED TEACHING APPROACH ON THE GRADE 10 LEARNERS' CONCEPTUAL UNDERSTANDING OF CHEMICAL CHANGE IN PHYSICAL SCIENCES.

Date: March 2022

Grade 10 Science Teacher
……………………….Secondary School
Tel:.............................. Email:………………………….

Dear Sir/Madam

I, Nkosinathi Willy Nkosi am doing research under supervision of Prof A.T Motlhabane, a Professor in the Department of Science and Technology Education towards an M Ed degree at the University of South Africa. I am requesting for permission to conduct a study in Ehlanzeni District titled: THE EFFECTS OF AN INQUIRY-BASED TEACHING APPROACH ON THE GRADE 10 LEARNERS' CONCEPTUAL UNDERSTANDING OF CHEMICAL CHANGE IN PHYSICAL SCIENCES.

The aim of the study is to determine the effects of an inquiry-based teaching approach on the Grade 10 learners' conceptual understanding of chemical change in Physical Science with the view of improving their performance in the subject.

The Ehlanzeni School district has been selected because it consists of schools from different quintile levels which will allow the research to gather data that will give a true reflection of the challenges faced by learners in Physical Science, and also because it is closer to the researcher.

The study will entail gathering quantitative and qualitative data from approximately 160 Physical Science Grade 10 learners in four different high schools through pretest and posttest, and semi structured focus group interviews respectively.

According to the 2021 National Senior Certificate Diagnostic Report, part 1 for content subjects, learners still struggle to answer problems that requires them to possess problem-solving skills, be analytical and evaluative. Therefore, the study is aimed at determining the effect of inquiry-based approach on learners' conceptual understanding which is described as key in enhancing problem solving skills in learners. Moreover, the study is expected to provide answers on whether the implementation of inquiry-based teaching approach improves science learners' conceptual understanding which will eventually improve their performance in the subject. The research will also highlight on the benefits of the implementation of inquiry-based approaches in science classrooms rather than the traditional approaches that many science teachers still utilize in their science classrooms.

There is no emotional or physical harm anticipated to the participants since the study does not focus on learners' physical activity or learners' personal issues. Since the study is to be conducted in the midst of a global pandemic, I as the researcher will ensure that all the participants adhere to the COVID-19 guidelines during the research, such as recording of their temperatures, wearing of face masks all the time, washing of hands, sanitizing and social distancing.

There will be no reimbursement or any incentives for participation in the research.
Feedback procedure will entail making the summary of the results available to the participating school's libraries where they will be easily accessible to everyone.

Yours sincerely

___________________________ NKOSI NW (RESEARCHER)

APPENDIX F: A LETTER REQUESTING PARENTAL CONSENT FOR MINORS TO PARTICIPATE IN A RESEARCH PROJECT

Dear Parent

Your child is invited to participate in a study entitled: THE EFFECTS OF AN INQUIRY-BASED TEACHING APPROACH ON THE GRADE 10 LEARNERS' CONCEPTUAL UNDERSTANDING OF CHEMICAL CHANGE IN PHYSICAL SCIENCES.

I am undertaking this study as part of my master's research at the University of South Africa. The aim of the study is to determine the effects of an inquiry-based teaching approach on the Grade 10 learners' conceptual understanding of chemical change in Physical Science with the view of improving their performance in the subject and the possible benefits of the study are to provide answers on whether the implementation of inquiry-based teaching approach improves science learners' conceptual understanding which will eventually improve their performance in the subject.

I am asking for permission to include your child in this study because he/she is one of the grade 10 science learners in the selected school. I expect to have 39 other children in the school participating in the study.

If you allow your child to participate, I shall request him/her to:

- Complete two multiple choice tests of 20 marks each, one will be written at the beginning of the study (pretest) and the other one will be written at the end of the lessons after two weeks (posttest). The participants will write the tests in their respective classrooms during the Physical Science period, and each test is expected to take 30 minutes.
- Be available to take part (if selected) in a semi structured focus group interview where a group of eight learners will participate in a one day discussion of prepared questions that will take an hour after school in the school premises. The focus group interview will take place after the posttest has been written. The interviews aim to gather qualitative data on the perceptions of learners on their learning of chemical change under the traditional teaching method and the inquiry-based teaching method classroom environment. The use of interviews will supplement the findings of the pre-test and post-test so to provide in-depth understanding of the relationship (if any) between the inquiry-based teaching approach and the learners' conceptual understanding. The semi structured interviews will enable the researcher to investigate further about the perceptions of learners by allowing new ideas to emerge during the interviews. I therefore request permission to audio record the interviews so that I will be able gather all the relevant data that I will need to make conclusions.

Any information that is obtained in connection with this study and can be identified with your child will remain confidential and will only be disclosed with your permission. His/her responses will not be linked to his/her name or your name or the school's name in any written or verbal report based on this study. Such a report will be used for research purposes only.

There are no foreseeable risks to your child by participating in the study. Your child will receive no direct benefit from participating in the study; however, the possible benefits to education are that, the study will provide answers on whether the implementation of inquiry-based teaching approach improves science learners' conceptual understanding which will eventually improve their performance in the subject and will also highlight on the benefits of the implementation of inquiry-based approaches in science classrooms rather than the traditional approaches that many science teachers still utilize in their science classrooms. Neither your child nor you will receive any type of payment for participating in this study.

Your child's participation in this study is voluntary. Your child may decline to participate or to withdraw from participation at any time. Withdrawal or refusal to participate will not affect him/her in any way. Similarly you can agree to allow your child to be in the study now and change your mind later without any penalty.

The study will take place during regular classroom activities with the prior approval of the school and your child's teacher. However, if you do not want your child to participate, your child will still be expected to be in class since the content to be learned is part of the syllabus and will be examined on during formal tasks but his/her test scripts won't be marked or used in the study.

In addition to your permission, your child must agree to participate in the study and you and your child will also be asked to sign the assent form which accompanies this letter. If your child does not wish to participate in the study, he or she will not be included and there will be no penalty. The information gathered from the study and your child's participation in the study will be stored securely on a password locked computer in my locked office for five years after the study. Thereafter, records will be erased.

The benefits of this study are providing answers on whether the implementation of inquiry-based teaching approach improves science learners' conceptual understanding which will eventually improve their performance in the subject and will also highlight on the benefits of the implementation of inquiry-based approaches in science classrooms rather than the traditional approaches that many science teachers still utilize in their science classrooms

Potential risks are no risks anticipated during the study.

There will be no reimbursement or any incentives for participation in the research.

If you have questions about this study please ask me or my study supervisor, Prof Motlhabane Department of Science and Technology Education, College of Education, University of South Africa. My contact number is 0726136429 and my e-mail is 45380139@mylife.unisa.ac.za . The e-mail of my supervisor is motlhat@unisa.ac.za Permission for the study has already been given by ……………………………………and the Ethics Committee of the College of Education, UNISA.

You are making a decision about allowing your child to participate in this study. Your signature below indicates that you have read the information provided above and have decided to allow him or her to participate in the study. You may keep a copy of this letter.

Name of child:

Sincerely

______________________________	____________________________	________________
Parent/guardian's name (print)	Parent/guardian's signature:	Date:
_____________________________	_____________________________	________________
Researcher's name (print)	Researcher's signature	Date:

APPENDIX G: A LETTER REQUESTING ASSENT FROM LEARNERS IN A SECONDARY SCHOOL TO PARTICIPATE IN A RESEARCH PROJECT

THE EFFECTS OF AN INQUIRY-BASED TEACHING APPROACH ON THE GRADE 10 LEARNERS' CONCEPTUAL UNDERSTANDING OF CHEMICAL CHANGE IN PHYSICAL SCIENCES.

Dear ___________ Date ________________

I am doing a study on determining the effects of an inquiry-based teaching approach on Grade 10 learners' conceptual understanding of chemical change in Physical Science as part of my studies at the University of South Africa. Your principal has given me permission to do this study in your school. I would like to invite you to be a very special part of my study. I am doing this study so that I can find ways that your teachers can use to deliver lessons in better and interactive way. This may help you and many other learners of your age in different schools.

This letter is to explain to you what I would like you to do. There may be some words you do not know in this letter. You may ask me or any other adult to explain any of these words that you do not know or understand. You may take a copy of this letter home to think about my invitation and talk to your parents about this before you decide if you want to be in this study.

I would like to ask you to participate in the study that will involve writing a pretest and attending lessons for two weeks and thereafter writing a posttest. Furthermore, eight learners in your class will be selected to participate in focus group interviews to determine learners' perception of learning chemical change under the inquiry-based approach and the traditional approach classroom environment. Learners will be asked 10 questions related to learners' cohesiveness, learners' cooperation, teacher support, learners' confidence in the topic, and knowledge gain which are identified as perception indicators. Discussion in the focus group will take no longer that 60 minutes after school.

I will write a report on the study but I will not use your name in the report or say anything that will let other people know who you are. Participation is voluntary and you do not have to be part of this study if you don't want to take part. If you choose to be in the study, you may stop taking part at any time without penalty. You may tell me if you do not wish to answer any of my questions. No one will blame or criticise you. When I am finished with my study, I shall return to your school to give a short talk about some of the helpful and interesting things I found out in my study. I shall invite you to come and listen to my talk.

The benefits of this study are the development of conceptual understanding of scientific concepts which is described as key in developing critical thinking and problem-solving skills which are vital in science

learning. The study will furthermore highlight on the benefits of the implementation of inquiry-based approaches in science classrooms rather than the traditional approaches that many science teachers still utilize in their science classrooms.
There is no emotional or physical harm anticipated to the participants since the study does not focus on learners' physical activity or learners' personal issues. Since the study is to be conducted in the midst of a global pandemic, I as the researcher will ensure that all the participants adhere to the COVID-19 guidelines during the research, such as recording of their temperatures, wearing of face masks all the time, washing of hands, sanitizing and social distancing.

You will not be reimbursed or receive any incentives for your participation in the research.

If you decide to be part of my study, you will be asked to sign the form on the next page. If you have any other questions about this study, you can talk to me or you can have your parent or another adult call me at 0726136429. Do not sign the form until you have all your questions answered and understand what I would like you to do.

Researcher: NKOSINATHI WILLY NKOSI Phone number: 0726136429

Do not sign the written assent form if you have any questions. Ask your questions first and ensure that someone answers those questions.

WRITTEN ASSENT

I have read this letter which asks me to be part of a study at my school. I have understood the information about my study and I know what I will be asked to do. I am willing to be in the study.

___________________________ ______________________ ______________________

Learner's name (print): Learner's signature: Date:

___________________________ ________________________ ______________________

Witness's name (print) Witness's signature Date:

(The witness is over 18 years old and present when signed.)

___________________________ ___________________________ _____________________

Parent/guardian's name (print) Parent/guardian's signature: Date:

__________________________ ___________________________ ________________________

Researcher's name (print) Researcher's signature: Date:

APPENDIX H: FOCUS GROUP ASSENT AND CONFIDENTIALITY AGREEMENT

I____ grant assent that the information I share during the focus group may be used by NKOSINATHI NKOSI for research purposes. I am aware that the group discussions will be digitally recorded and grant assent for these recordings, provided that my privacy will be protected. I undertake not to divulge any information that is shared in the group discussions to any person outside the group in order to maintain confidentiality.

Participant‘s Name (Please print): ___________________________________

Participant Signature: ____

Researcher’s Name: (Please print): NKOSINATHI WILLY NKOSI

Researcher’s Signature: ____

Date: ____

APPENDIX I: SCHOLASTIC TEST

LEARNER CODE: ……………………………………

PRETEST/POSTTEST MARKS: 20

GRADE 10: PHYSICAL SCIENCE

TOPIC: CHEMICAL CHANGE (PHYSICAL & CHEMICAL CHANGE; REPRESENTING CHEMICAL CHANGE)

DURATION: 30 MINUTES

MULTIPLE CHOICE: **FOUR** answers are provided as possible answers, but only **ONE** answer is **CORRECT**. Chose the correct answer and write it in the provided box on the right.

1. INTERPRETE

1.1. Study the following equation:

$Zn + 2HCl \rightarrow ZnCl_2 + H_2$

The equation can be written in words as:

A. Zinc + Hydrogen Chloride → Zinc Chloride + Hydrogen

B. Zinc + Hydrogen Chloride → Zinc Chloride + Hydroxide

C. Copper + Hydrogen Chloride → Zinc Chloride + Hydrogen

D. Zinc + Hydrogen Chlorine → Zinc Chloride + Hydrogen

1.2. In the following equation:

$Cu_{(s)} + H_2SO_{4(aq)} \rightarrow CuSO_{4(aq)} + H_{2(g)}$

the PHASES of the substances can be orderly written as:

A. Solid; Liquid; Aqueous; Gas

B. Solid; Aqueous; Aqueous; Gas

C. Liquid; Aqueous; Aqueous; Gas

D. Solid; Aqueous; Aqueous; Solid

2. COMPARE

2.1. Select the features applicable to PHYSICAL CHANGE.

(i) No new product is formed.

(ii) New product is formed

(iii) Melting of ice

(iv) Burning of coal

The following combination of features are ONLY applicable to PHYSICAL CHANGE.

A. (i) only
B. NONE
C. (i), (ii) and (iv)
D. (i) and (ii)

2.2. In the compound, H_2O, the ratio of the MASS of hydrogen to oxygen is always…….

A. 1:2
B. 2:1
C. 1:8
D. 1:16

3. EXPLAIN

3.1. Chemical change is defined as:

A. a change during which a new substance with new properties is formed.
B. a change during which no new product is formed.
C. an amount of matter in the body.
D. a change from liquid water to gaseous water.

3.2. Which ONE of the following statements is INCORRECT about the properties of a physical change?

A. When a physical change occurs the compounds may rearrange themselves but the bonds in between the atoms will not break.
B. Physical change in matter is reversible.
C. Energy is absorbed when matter changes from a solid to a liquid.
D. Molecules are not conserved during a physical change.

4. INFERENCE

4.1. Which one is an example of a chemical change?

A. Boiling of water.
B. Melting of chocolate.
C. Burning of petrol.

D. Sublimation of dry ice.

4.2. In a certain reaction, the total MASS of the particles of reactants was found to be 25g before the reaction. At the end of the reaction, the MASS of the particles of the products was calculated and was found to be 25g. Which law best describes the observation made with regards to the mass of the reactants and products?

A. Law of conservation of mass
B. Law of conservation of matter
C. Law of volume relationships in gas reactions
D. Law of conservation of momentum

5. CLASSIFY

5.1. Choose the correct set of examples of chemical and physical changes.

	CHEMICAL CHANGE	**PHYSICAL CHANGE**
A	Clay is rolled into a ball	Mercury oxide separate into mercury and oxygen
B	Ice cream melts	Sugar is dissolved in water
C	Coal is burned and forms carbon dioxide and water	Water evaporates
D	Perfume evaporates	Iron sheets are cut into strips

5.2. Choose the correct set of equations that represents chemical and physical change.

	CHEMICAL CHANGE	**PHYSICAL CHANGE**
A	$H_2O_{(l)} \rightarrow H_2O_{(g)}$	$H_2O_2 \rightarrow H_2 + O_2$
B	$H_2O_2 \rightarrow H_2 + O_2$	$H_2O_{(l)} \rightarrow H_2O_{(g)}$
C	$H_2O_2 \rightarrow H_2 + O_2$	$Zn + HCl \rightarrow ZnCl_2 + H_2$
D	$H_2O_{(l)} \rightarrow H_2O_{(g)}$	$Zn + HCl \rightarrow ZnCl_2 + H_2$

APPENDIX J: FOCUS GROUP INTERVIEW QUESTIONS

Semi-structured Focus Group interview

Topic: Find out learners' perceptions on their learning of chemical change under the inquiry-based approach and the traditional approach classroom environment

Group code:...............................

Duration of the interview: 1 hour

INTRODUCTORY QUESTIONS:

1. You attended lessons about chemical change in the last two weeks, how were the lessons?

PROBING AND FOLLOW-UP QUESTIONS:

Learners' confidence

2. Did you enjoy learning chemical change? Why?
3. Are you confident enough to share what you learned about chemical change with the group?

Teacher support

4. Was there a point during the chemical change lessons that you felt you are no longer following what was being taught? How did you pass through that point?
5. Do you believe there was enough assistance from your teacher during the lessons?

Learners' cohesiveness/ cooperation

6. Did you play any role during group discussions in class? Elaborate.
7. Were you actively participating in class during the chemical change lessons? If not, why?

Knowledge gain

8. Did you perform the same way in your pretest and posttest? If not, why?
9. Can you give any examples of applications of chemical change in everyday life?

CONCLUDING QUESTION:

10. Anything else you would like to add to our discussion?

APPENDIX K: EDITING AND PROOFREADING CERTIFICATE

PROOFREAD LETTER

GENEVIEVE WOOD

P.O. BOX 511 WITS 2050 | 0616387159

EDITING CERTIFICATE

LANGUAGE EDITING SERVICES

Date: 2022/11/30

This serves to confirm that the document entitled:

THE EFFECTS OF AN INQUIRY-BASED TEACHING APPROACH ON THE GRADE 10 LEARNERS' CONCEPTUAL UNDERSTANDING OF CHEMICAL CHANGE TOPIC IN PHYSICAL SCIENCES

By Nkosinathi Nkosi

has been language edited on behalf of its author, with recommendations for improvement.

Genevieve Wood
PhD candidate