EXPERIENCES OF PHYSICS TEACHERS WHEN IMPLEMENTING PROBLEM-BASED LEARNING

A CASE STUDY AT ENTSIKENI CLUSTER IN THE HARRY GWALA DISTRICT KWAZULU-NATAL, SOUTH AFRICA

BY

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DECLARATIONS

I proclaim that the *EXPERIENCES OF PHYSICS TEACHERS WHEN IMPLEMENTING PROBLEM-BASED LEARNING(PBL)*in their physics classrooms are my personal effort. Furthermore the entire sources used have been accredited in my references.

This bit of work is the outcome of my hard work from beginning to end under the proficient supervision and support of my supervisor whose name and signature are indicated beneath.

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DEDICATION

This study is wholeheartedly devoted to my beloved wife, RahinatuIddrisu who have been my source of inspiration and gave me the strength when I thought of given up. She continually provided her moral, spiritual, emotional and financial support.

And to my friends Abdul-Rashid Adam and Salifu Mohammed who shared their words of advice, encouragements and financial support to finish this study.

Finally, this effort is devoted to the omnipotent God on behalf of His direction, strength, power of mind, skills and protection for me throughout this study.

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ABSTRACT

Problem-based learning (PBL) is an active teaching strategy that could be implemented in the South African educational system to assist in developing problem-solving skills, critical thinking skills, collaborative skills, self-directed learning and intrinsic motivation in students. Even though it is not easy to drift from a teacher-centred strategy to a student-centred strategy, but this drift is supposed to be a paradigm drift for the nation. 'Physics is difficult' has been the anthem of students in South African high schools. This has led to lower pass rates in physics and as a result low physics career person in society. Physics students in high schools need to be exposed to the PBL strategy since the PBL strategy focuses on real-life problems to develop problem-solving skills, critical thinking skills and self-directed learning in students which are the skills needed for concept formation in Physical Science. Basically, the education of Physical Science students focused on the ability to acquire skills to solve real-life problems. This study focuses on exploring the experiences of high school physics teachers at Entsikeni cluster, South African, when implementing problem-based learning (PBL) in their physics classrooms. The study uses the mixed-method approach where three different research instruments were used to collect quantitative and qualitative data sequentially. Questionnaires, RTOP and interview protocol were employed. The findings of the study indicate that teachers project positive attitudes toward the PBL strategy but may probably not continue to use it because it requires more time than that which is allocated in the Curriculum Assessment and Policy Statement (CAPS) Physical Science document and as a result may not be able to finish their ATP on time. Teachers are teaching physics with no specialization in physics, which probably could lead to poor, pass rates in Physical Science. Teachers were inexperienced in teaching physics in the FET and could probably affect students' academic performance. It is recommended they apply the PBL strategy to correct the negative effect of their inexperience on students' performance. It is evident that if inexperienced trained teachers apply an instructional strategy based on research, they tend to develop students' performance as compared to applying the traditional instructional strategy.

KEYWORDS: *problem-based learning, inquiry-based learning*, *traditional lecture instructional strategy, teacher-centered strategy, learner-centered strategy*, *Physical Science, physics education, problem-solving skills, collaboration, critical thinking skills, self-directed learning, intrinsic motivation, outcome-based education*

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LIST OF ABBREVIATIONS

Q1BI	Questionnaire 1 before Intervention
Q2AI	Questionnaire 2 after intervention
PBL	Problem-based learning
IBL	Inquiry-based learning
CAPS	Curriculum Assessment and Policy Statement
NCS	National Curriculum Statement
RTOP	Reform Teaching Observation Protocol
ATP	Annual Teaching Plan
GET	General Education and Training
FET	Further Education and Training
DoE	Department of Education
DBE	Department of Basic Education
OBE	Outcome-Based Education

CHAPTER ONE
OVERVIEW OF THE STUDY

1.0 INTRODUCTION

Efficient education in Physical Science requires active student involvement and the provision of educational resources (Hersh, 1983). This claim is consistent with the views of Sanders, Borko and Lockard, (1993) who stated that it is significant to facilitate students to build their personal understanding by learning by doing. Physics students must be encouraged to engage in actual tasks through research, investigation and experimentation, which emulate what scientist do in real-life situations.

A possible way of addressing these claims is by introducing the problem-based learning (PBL) strategy. This is an active instructional strategy that can increase students' understanding of scientific concepts (Dole, Bloom &Kowalske, 2016). Problem-based learning (PBL) is an active teaching approach which originated from the principles of a teacher and philosopher John Dewey (1959). Dewey (1959) argued on the basis that the PBL strategy is an effective teaching and learning strategy which could increase students' involvement and instil an in-depth understanding of materials. When students are involved in activities solving problems that are real and meaningful to them in real-world settings, it turns to create interest and motivation (Dewey, 1959).

Over the years, the strategy applied to teach physics does not give students the chance of being enthusiastically involved during activities (Squire & Jenkins, 2003). The consequence of this is the complaint from students that physics is difficult. This discourages them to study physics and as a result, could direct towards unfortunate presentation in the subject.

The reasons for researching this pedagogy is that the traditional instructional strategy starting after kindergarten to the high school level often graduates students who have a negative attitude towards physics education (Barrows, 1996). In the traditional method, students tend to memorise which sometimes is seen irrelevant to our everyday lives (Orlich, Harder, Callahan, Trevisan& Brown, 2012). The need for a

research-based instructional strategy that builds on an ill-structured problem to build in pupils the skills in problem-solving is therefore important (Norman & Schmidt, 2000). The strategy uses an ill-structured question or a driving question to stimulate students' critical thinking ability. Problem-based learning (PBL) is the instructional strategy which has essentially moved the practices of the classroom from tutoring to that of focussing on learning (Kiraly, 2005). A sound knowledge in addition to skills in the use of PBL by physics teachers will increase their competency in teaching physics, improve learners' achievement, sustain learners' interest and motivate them to study physics at the higher level of learning (Hong, Yam, & Rossini, 2010).

Even though students in South Africa over the years have complained physics is difficult, it does nevertheless remain an important subject for them. In fact, the hi-tech potentials of every country including South Africa may perhaps be more precisely measured through the eminence of its physics education (Tunde, Akintoye, &Adeyemo, 2011). Research has affirmed that without physics, the technological culture of the citizenry of any nation cannot be firmly rooted (Tunde, Akintoye, &Adeyemo, 2011). Physics education and research therefore are the backbone to national transformation such that, according to Tunde et al.,(2011) and Josiah (2011), physics develops in students the basic knowledge required for future technological advancement to steer the trade and industry potentials of a nation and humanity at large. Furthermore, they indicated that physics contributes to the hi-tech infrastructure and provides skilled human resources required to take advantage of scientific advances and discoveries. More so, physics education and research form the basis of educating professionals such as chemists, engineers and computer scientists, as well as other professionals of physical and biomedical science. They however emphasised that physics improves the quality of life through its applications in the medical field in areas such as computer tomography, magnetic resonance imaging, positron emission tomography, ultrasonic imaging and laser surgery. Finally, it inspires the youth and expands their knowledge of nature (Tunde et al., 2011 and Josiah 2011). To this end, students require to be trained to study using an active learning strategy, such as the PBL, that could create fun, interest and motivation to study physics while improving their understanding of scientific concepts.

1.1 BACKGROUND TO THE STUDY

A drop in the metric pass rate is noticed in South African student attainment in Physical Science (Physical Science combines the subject's physics and chemistry) from 2004 to 2009 and from 2013 to 2015. These drops in the pass rate could be attributed partly to lack of resources and largely to the teaching strategy, amongst others. Research has proven that one of the reasons for the poor pass rate could be attributed to poor teaching methods (Muzah, 2011).

Table 1.1: The results from 2004 to 2017

Year	Pass rate	Year	Pass rate
2004	70.7%	2011	70.2%
2005	68.3%	2012	73.9%
2006	66.5%	2013	78.2%
2007	65.2%	2014	75.8%
2008	62.7%	2015	70.7%
2009	60.6%	2016	72.5%
2010	67.8%	2017	75.1%

Department of education exams results/ www.dbe.gov.za

The slight increase in the last two years could possibly be attributed to the various metric intervention programs by the various provincial departments. In the KwaZulu-Natal provincial department of education winter classes, spring classes, weekend classes and Just In Time (JIT) programs are organized to assist metric students in attaining better results. Nevertheless, there is the call for a holistic move towards solving this crisis to include all students in the Further Education and Training (FET) phase, not only grade 12 students, in any intervention aimed at improving performance.

Meanwhile, research has shown that teachers are still applying the traditional instructional strategy (Bean, 2011). However, this is done despite the effort by science education researchers to come up with effective methods of teaching physics that intensify students' engagement and to assist them in developing an unfathomable understanding of scientific concepts (Bean, 2011). The introduction of the Outcome-

based educational (OBE) system in South Africa in 1997 should have been a paradigm shift from the traditional instructional strategy but yet the system was not sustainable due to the challenges of implementing student-centred strategy in developing countries (Guthrie, 2017). The traditional instructional strategy dwells more on memorising scientific concepts and less on students' investigation (Squire & Jenkins, 2003; Rollnick, Bennett, Rhemtula, Dharsey, and Ndlovu, 2008). Krajcik and Czerniak (2014) opined that memorising scientific concepts only results in superficial understanding. However, researchers have shown that this strategy only ensures that students pass an examination and not necessarily develop concepts that will make them problem-solvers (Krajcik and Czerniak, 2014); hence the expression ‘chew and pour, pass and forget'. The strategy has not been able to motivate students to study physics and the fact remains that students pursuing careers in physics remains very low (Osborne, Simon, & Collins, 2003).

Yet another problem that contributes to poor pass rate could be attributed to inappropriate physics textbook design (Krajcik and Czerniak, 2014). Physics textbooks are designed to feed students with information but not to make them problem-solvers. As a result, the traditional physics teacher occasionally gives students an investigation or a project to work on but follows the exact sequence of steps in these textbooks. However, this rarely affords students the opportunity of exploring materials in a real-world context (Krajcik and Czerniak, 2014). Kesidou and Roseman (2002) warns that following the exact sequence of steps in a textbook, which is referred to as the cookbook procedure, does not necessarily make students problem-solvers.

Furthermore, it could be noted that students in South Africa are taught in large class sizes (Onwu & Stoffels, 2005). Teachers' competencies in teaching large classes remains a challenge (Onwu & Stoffels, 2005) and this also may perhaps add up to reduced pass rate in physics. Consequently, students may hide behind others and therefore do not participate actively in class activities. As a result, it could probably lead to poor performances in class and subsequently poor pass rates. In view of this, the need for a pedagogy that will enthusiastically engage all students in the teaching and learning process that could probably improve students' performance therefore is of paramount importance.

The various reform programs in the South African educational system since1994 described as the post-apartheid educational reforms have failed to address students' concerns in Physical Science, Department of Basic Education (DBE) (2009c). Curricula changes in post-apartheid South Africa recount the introduction of the Outcomes Based Education (OBE) curriculum after the Bantu Education Act of 1959 (Tabata, 1997). The OBE got under way with the South Africa's Ministry of Education in 1997. It stressed the desires to create self-determining and critical thinkers who are competent to question, reflect on facts, formulate conclusion and be acquainted with the imperfect nature of knowledge (Republic of South Africa (RSA), 1996). The OBE system also recognized as the Critical Outcomes propose that students should be able to "categorize and solve problems and formulate conclusions using critical and innovative thoughts" (Department of Education (DoE), 2002, p. 12). The outcome-based education curriculum can therefore be distinguished as results-oriented, which is a reverse to input-based education where the prominence is on the learning process (Jansen, 1998). According to (Pretorius, 2008), OBE had severe challenges such as; budgetary restraint, thoughts of parents that their children are used as guinea pigs to test drive a curricula change, lack of resources, complain by teachers for doing a lot of work (example tracking learner progress), lack of training of teachers on the required skills needed to man the OBE strategy, among others. This suggests that the OBE could not solve South Africa educational problems (Pretorius, 1999).

Due to the challenges that were identified as constraining OBE, the National Curriculum Statement 2002 (NCS) was introduced (Department of Education (DoE), 2002). Differing from the OBE curricula, the NCS curricula required that students in grades 10, 11 and 12 study a least of 7 subjects. In addition students are anticipated to study two South African languages and an unavoidable selection among Mathematics and Mathematical Literacy, as well as Life Orientation. The National Curriculum Statement (NCS) 2002 was anticipated to be subjected to modification under the proposal of the Ministerial Committee on curriculum to make it further reachable to teachers. It then became the Revised National Curriculum Statement 2015 (Department of Education (DoE), 2009). The fact still remains that even the execution of the 2015 National Curriculum Statement (NCS) has not been able to save the situation (Hoadley, 2017). Furthermore, the prologue of the Curriculum Assessment and Policy Statement (CAPS), which was operational in January 2012

across all phases from grade R to high school in South Africa Department of Basic Education (DBE) (2011b), has not been able to address the situation. Following the submissions above it is quite clear that the reform strategies and the attempts to make it teacher-friendly could not change realities in the classroom. However, the question remains: how can we improve the teaching and learning of physics in the South African schools?

Ironically, in addition to the revision of physics textbooks and provision of well-resourced science laboratories, there is the need for a teaching strategy that will intensify students' engagement and assist them in developing problem-solving skills (Bantwini, 2010). Research has shown that by engaging in the actual project, students acquire a deeper understanding of materials, obtain new ideas and use the knowledge gain to solve life problems (Krajcik&Czerniak, 2014). Following these arguments there is, therefore, the necessity to carry out instructive study to discover a teaching strategy that could develop problem-solving skills in students, improve their performance and subsequently improve the pass rate in Physical Science in high schools. This would possibly motivate students and sustain interest in them in the study of physics.

1.2 THE RATIONALE OF THE STUDY

Problem-based learning (PBL) is a teaching approach not often used within South African schools. Various reasons could be offered such as social motives: students reluctant to work in groups; educational motives: stress in following the ongoing rhythm of PBL; educational method: difficulties in changing from the long-standing traditional lecture instructional strategy; and mode of examination where students have to learn specific content; educational content: difficulties in integrating various disciplines – which is one of the characteristics of PBL. However, by introducing this teaching strategy in physics could link academic situations to everyday problems for deeper understanding. This initiative could possibly address the decreasing standards of Physical Science in the Harry Gwala district. In addition, it could motivate teachers to learn and apply an instructional approach that focuses on the students' erudition not the teachers' teaching, which eventually could lead to motivation and self-directed learning.

The outcome-based educational strategy which was launched in South Africa in 1997 is similar to the problem-based learning educational strategy. According to Pretorius (1999), they share some exclusive characteristics which make them attracted to educational systems. The OBE system was not sustainable because of the many challenges it faced. According to Pretorius 2008, one of the key challenges is that the training offered to teachers on how to handle the OBE curriculum is awfully in adequate. The emphasis is on physics teachers needing sound content understanding and pedagogical skills in the use of PBL strategy. Therefore, both newly trained and experienced high school physics teachers are required to experience continuous professional development to furnish them with this alternative pedagogy (PBL). This could increase their competency in teaching and learning physics, improve learners' achievement, sustain students' interest and motivate them to study physics at higher level of learning (Hong Sharon Yam & Rossini, 2010).

Research has affirmed that students who are trained with problem-based learning (PBL) strategies achieve improved learning results compared to those taught in the conventional classroom (Freeman, Eddy, McDonough, Smith, Okoroafor, Jordt & Wenderoth, 2014). This claim is consistent with the views of Hong Sharon Yam and Rossini (2010). They, however, stated that the constructive impression of the PBL strategy on high school students' attainment is long-established through their achievement in entering advanced educational institutions. However, the two basic requirements for successful implementation of a PBL curriculum are small number of students in groups and sufficient economic resources to make available both equipment and libraries for exploitation by both students and teachers (Carrera, Tellez & D'Ottavio 2003). This claim is consistent with the views of Anderson and Glew who said that a popular argument against PBL is that it is costly in terms of money, time and space. To this end, it is difficult for a PBL curriculum to be implemented successfully in developing country like South Africa due to it large class sizes and inadequate supply of educational materials (Guthrie, 2017).

1.3 THE SIGNIFICANCE OF THE STUDY

The contemporary research is designed to explore the experiences of physics teachers in the Entsikeni cluster, Harry Gwala district, when implementing an alternative teaching method, namely problem-based learning. These teachers will also be granted the opportunity of testing it in their classrooms and of reflecting on the practice of using PBL.

The outcome of the research may perhaps update other teachers and department officials about a different approach to active learning where students connect academic situations to the real world, develop interpersonal relationships, improve problem-solving skills and develop intrinsic motivation. The successes of this research will perhaps influence teachers in other schools in the district to adopt the PBL strategy in teaching their physics students. This will, however, assist in preparing the students to live successfully in the global 21st-century society (Ananiadou, & Claro, 2009).

1.4 THE RESEARCH PROBLEM

The method of teaching and learning physics where students must memorise formulae and apply them in word problems is still used extensively in schools (Krajcik&Czerniak, 2014). The strategy is applied despite the effort by researchers in science education to introduce alternative strategies. With this method of memorising formulae and applying it in word problems students only acquire superficial understanding rather than an integrated understanding to facilitate problem-solving skills, make decisions, and learn new ideas (Sawyer, 2006). Consequently, this has resulted in producing physics students who are demotivated (Krajcik, & Czerniak, 2014) and this could probably have resulted in physics students not showing interest in continuing their education in physics in higher learning.

Nevertheless, experience over the years in teaching Physical Science in Dulati Combined School, in South Africa at the Entsikeni cluster has shown that even best students in Physical Science end up doing nursing or courses that are related to life sciences and not physics. Moreover, research has affirmed that the number of

students pursuing careers in physics remains very low (Osborne et al., 2003). The fact remains that in the past, less than 0.5% of South African students attain university entry in science and mathematics (Erasmus & Breier, 2009). As a result, various strategies were adapted to help improve the situation. However, in recent times, strategies have targeted on growing resources in science education by training additional science teachers, giving access to more students to study science at the basic school level and the provision of more science resources (Naidoo & Lewin, 1998). In South African schools, while the curriculum in the General Education and Training (GET) phase (Grades R - 9) has a learning area called technology that helps students to learn how to create tangible products which improves students' creative skills (Department of Education (DoE), 2002b), the Further Education and Training (FET) phase (Grades 10 – 12) does not include technology (Department of Education (DoE), 2003). In this phase, learners need to select subjects, which follow a career path, and technology does not form part of the choices. As a result, a physics teacher at the Further Education and Training (FET) phase (Grades 10 – 12) therefore needs to teach physics with technology to develop in students the skills to create artefacts.

However, recent science education specialists have introduced an alternative strategy, namely problem-based learning (PBL) that integrates science and engineering practices (Organisation for Economic Co-operation and Development (OECD), 2007). Possibly, the strategy emphasises the students' learning and not the teachers' teaching (Organisation for Economic Co-operation and Development (OECD), 2007). Nonetheless, it does develop in students the skills to link academic situations to real-world situations (Krajcik & Czerniak, 2014).

Much needs to be done to determine the experiences of teachers in PBL in the school setting (Rico & Ertmer, 2015). It is for this reason that a professional development intervention for selected teachers will be organized to develop in them the skills in organizing a PBL class for a deeper understanding and sustaining the interest of learners in physics. This study chooses to explore the experiences when physics teachers use PBL to teach physics in high schools to verify the perception of PBL as a hopeful teaching strategy in enhancing students' skills in problem-solving, independent learning, conceptual understanding, and built-in inspiration is warranted.

1.5 RESEARCH AIM AND OBJECTIVES

The aim of the research is:

To explore the experiences of physics teachers in the Entsikeni cluster, Harry Gwala district, when implementing an alternative teaching method, namely problem-based learning.

The objectives that guide the study are:

1. To ascertain what physics educators' understanding is of the use of PBL, prior to the intervention;
2. To develop an intervention on the practices of PBL in a physics classroom;
3. To determine how these physics teachers, implement PBL in their classrooms; and
4. To determine the successes and challenges of these teachers when using PBL in their classrooms.

1.6 RESEARCH QUESTIONS

The central research issue for this learning is:

What are the experiences of physics teachers when implementing Problem-Based Learning (PBL)in their classrooms?

Three sub-questions were developed, namely:

1. What are physics teachers' experiences when implementing PBL, prior to the intervention?
2. How do these physics teachers implement PBL in their classrooms?
3. What are the successes and challenges of these physics teachers when using PBL in their classrooms?

1.7 LIMITATIONS OF THE STUDY

The restrictions to the study are:

1. The motive intended for selecting these physics teachers was to establish their experiences when implementing problem-based; not to search for possible factors causing learners to fail physics.
2. The populace was Grade 10 and Grade 11 Physical Science teachers randomly selected from community high schools in the Entsikeni cluster; therefore, the findings cannot be generalized.
3. Learners in Grade 10 and Grade 11 Physical Science class of the selected schools were the centre of attention, and not other grades such as Grade 12.
4. One of the main crises opposing didactic research in South Africa is funding. No additional funds were used during the workshops and teachers attended voluntarily without any financial support.

1.8 OUTLINE OF CHAPTERS

The chapters of the study have been arranged as follows:

***Chapter One*:**

This chapter discussed the alignment of study and dealt with the following sub-headings: introduction, the underlying principle of the study, the implication of the study, the declaration of the dilemma, the research question, the aims and objectives and limitations of the research.

Chapter Two:

This chapter sets the tone for reviewing the literature for the study. Information from this chapter is used as evidence during analysis and presentation.

Chapter Three:

Chapter three discusses the study methodology, research plan, research instruments, dependability and rationality of the instrument, sampling procedures, information techniques, data examination, participants, and location of study, interventions and ethical considerations.

***Chapter Four*:**

Chapter four focuses on data representation, analysis and interpretations applying an arithmetical strategy in a form of tables and graphs, and on using themes.

Chapter Five:

This chapter discusses and reports the explanation of what was the evidence discovered by the analyses. This led to the summary, inference and endorsements for future studies.

1.9 SUMMARY OF THE CHAPTER

Physics is one of the science subjects integrated into Physical Science instruction in the South African school system. It has been a national problem even after the introduction of the National Curriculum Statement (NCS) in 2005 and the Curriculum Assessment and Policy Statement (CAPS) Physical Science in 2012, as the number of Grade 12 students who pass Physical Science remains very low. In view of this, the need exists to introduce another teaching strategy in physics that could improve Physical Science education and motivate learners to study physics at a higher level. Chapter one of this study provides a concise account of why the researcher embarked on this research and the input of the research to the South Africa basic education. The chapter as well explains why physics teachers are required to revolutionize the conventional technique of instruction to the PBL approach. Research has proven that the PBL strategy intensifies students' engagement, develops investigative skills and motivates students. The next chapter discusses extensive literature on PBL and sets the theoretical framework and review of the study. In relation to the rationale of the

study, the next section will also discuss the gap which this study is to fill and is set to demonstrate how the research question fits into a larger field of study worldwide and in South Africa

CHAPTER TWO
LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 INTRODUCTION

In the review of the literature, the procedure for teaching and learning in science is discussed (see section 2.2) as well as different teaching strategies (see section 2.3). However, the focus was to present the advantages and disadvantages of the teacher and learner-centred teaching strategies (see sections 2.3.1 and 2.3.2). Hence the lack of appropriateness of the teacher-centred strategy was presented (see section 2.4.2). This paved the way to introduce the PBL instructional strategy (see section 2.4). The theoretical framework is discussed in section 2.11

2.2 THE PROCESS OF TEACHING AND LEARNING SCIENCE

Learning

Learning occurs once experiences originate a comparatively lasting change in a person's performance (Woolfolk, 2010). This revolutionize may perhaps be thoughtful, aware or unaware, correct or mistaken (Woolfolk, 2010). The change in behaviour is brought about as a result of individuals interacting with the environment. Hence the changes that indicate that a person has learned must result from the persons' behaviour (Woolfolk, 2010). Slavin (2011) explains that learning is cooperative since it is situated in a social context. The central conception of most constructivists is viewing learning as a cooperative and social process. Even though constructivists consider learning to be cooperative and in a social context, Yackel, Cobb, & Wood, (1991) however emphasize that social interaction is important for science learning, with individual knowledge construction. This suggests that students can acquire concepts and skills through social interactions regardless of the idiosyncratic processes of learning. This process of learning is regarded as important because knowledge itself is developed through history, and interaction with the social environment. Therefore, as Li and Lam (2013) suggest, learning is achieved through the process of development; such that students must participate actively in the learning process.

Teaching

Teaching is the intensive effort of sharing information and skill, which is more often than not prearranged within a discipline and provides a motivation to the psychosomatic and academic development of a person by another person (Impedovo&Iaquinta, 2013). Thus, teaching involves two consecutive processes: planning and execution (Anderson, Greeno, Kline, & Neves, 1981). The teacher's teaching must be planned, well packaged and presented to the student in a logical and sequential manner with the objective of sharing experience. Nevertheless, Anderson et al., (1981) postulates that preparation influences what learners learn for the reason that preparation wholly transfers the existing moment and programme of study into activities for students to practice on. After a lesson has been planned it has to be put into action.

2.3 TEACHING STRATEGIES

Enríquez, De Oliveira, and Valencia (2018) defined 'teaching strategies' as the guiding principle the teacher integrates meant for promoting knowledge. They further explain that teaching strategy is a learning circumstances provided by the teacher (Enríquez et al., 2018). In other words, it is a state of affairs during which the teacher proposes a kind of task (exercise, problem, exploration, research, etc.) to invite the students to investigate it (Enríquez et al., 2018). A professor giving directions to his students to build up in them the capability to interpret information found in a task is a form of a teaching strategy. Villota, Villota, and González (2017) recommend that instructional strategies are fundamentals a teacher employs throughout his pedagogical practice.

The selection of a teaching technique depends on the teacher, the students' needs as well as the concept to be introduced (Anijovich& Mora, 2009). McDermott, Shaffer and Somers (1994) and Mazur (1996) point out that the teacher must ensure that the teaching strategy to be used:

1. teaches the scientific way of thinking
2. actively involves students in the teaching and learning process
3. assists students in developing problem-solving skills
4. assists students in developing a conceptual framework

5. should promote students' discussions and group activities
6. should create interest and motivation

Teachers apply different teaching strategies, the teacher-centred teaching strategy and the learner-centred teaching strategy will be discussed.

2.3.1 Teacher-Centred Teaching Strategy

The teacher-centred teaching strategy is a frequently applied technique by teachers, especially when teaching large class sizes and older students (Çetin, &Özdemir, 2018). The strategy focuses on the passive acquisition of knowledge. Students are expected to take notes and absorb information by memorising (McDermott & Shaffer, 1994). Students are therefore observers and react to teachers' instructions by answering questions verbally or in written form (McDermott & Shaffer, 1994). The teacher does much of the work by lecturing or questioning and expects answers from the students (Zakaria&Iksan, 2007). Occasionally the teacher may employ discussions yet would still dominate the class situation. The strategy is therefore characterised by massive domination of the teacher and students memorising concept (McDermott & Shaffer, 1994).

Researchers have affirmed that memorising concepts and information is not an important talent in this 21st century (Squire & Jenkins, 2003; Rollnick et al., 2008). Even though the strategy has proven to be effective in other subject areas, research has shown that in physics, lectures do not assist students to build up conceptual understanding of the physics concept (Arons, 1983; McDermott & Shaffer, 1992; McDermott et al., 1994; Michael, 2006). Research affirmed that the teacher-centred teaching strategy is less effective in promoting students' conceptual understanding of science (Mji&Makgato, 2006).

2.3.1.1 Advantages of the teacher-centred teaching strategy

Allen (2004) accentuates that teachers applying the teacher-centred teaching strategy wrap subject matter more rapidly for the reason that students are mainly inactive and

just sit back and take note from the teacher. The strategy is less costly because it does not engage the exploitation of apparatus or a laboratory (Çetin&Özdemir, 2018). Furthermore, the strategy develops students' listening skills as the process is characterized by long talks of the teacher (Çetin&Özdemir, 2018).

2.3.1.2 Disadvantages of the teacher-centred teaching strategy

In the teacher-centred teaching strategy, teacher-student interaction and student-student interactions which help to develop collaboration are less significant (Jaques& Salmon, 2007; McCarthy & Anderson, 2000). Furthermore, students compete for better examination scores instead of cooperating and concept learned tend to be superficial (Jaques& Salmon, 2007; McCarthy & Anderson, 2000). Moreover, the strategy is unable to give teachers information on the psychological and behavioural attitudes of their students (Salehizadeh, &Behin-Aein, 2014). According to Allen (2004), central learning purpose such as communication as well as information literacy skills possibly will not be learned by students since they are predominantly silent and merely listen to the teacher. He further emphasized that in the teacher-centred teaching strategy learners are less engaged and as such, inactive in the teaching-learning progression.

Moreover, as indicated by McNeill and Krajcik (2009) and Pellegrino, Chudowsky, and Glaser (2001), the process is characterized by long talks by the teacher and less attention to students' response and feedback. As a result, teaching and learning are devoid of practical or real-life situations and evidence of learning is based on lecture notes and students' textbooks (Orlich, Harder, Callahan, Trevisan, & Brown, 2012). This strategy is identified to be unsuitable for teaching lower grades because there is little or no interaction with the teacher (Michael, 2006). Studies have proven that in the teacher-centred strategy, information is made readily available, and student need not search for them (McDermott & Shaffer, 1992). Orlich et al., (2012) explain that students learn by memorising without understanding and as a result fact may change during memorization.

However, from the above discussions, it could be noted that the teacher-centred strategies does not assist learner to develop conceptual understanding of the Physical

Science theory (Karaçalli&Korur, 2014) In the teacher-centred strategies, students are not actively involved and as a result are not given the opportunity of developing problem-solving, critical thinking skills, effective collaborative skills, self-directed learning and motivation (Karaçalli&Korur, 2014). Therefore, the need exists for an alternative strategy, namely the learner-centred strategy which actively engages students in the teaching and learning process and assists them in developing the 21st-century skills.

2.3.2 The Learner-Centred Teaching Strategy

The learner-centred teaching strategy shifts the centre of attention of teaching from the teacher to the learner (Huba & Freed, 2000). They further emphasized that for efficient instruction and knowledge acquisition of science, teaching must move from the teacher's instruction to students learning such that the teacher merely act as a catalyst in the teaching-learning process (Huba & Freed, 2000). Lukinbeal, Kennedy, Jones, Finn, Woodward, Nelson, Grant, Antonopolis, Palos, and Atkinson-Palombo (2007) caution teachers not to be the active agent and leave the learners to be passive vessels. Instead, they maintain that the classroom should be a place of dialogue and collaboration. Kahl and Venette (2010) also reinforced this belief by asserting that the goal of learner-centred education is to shift the focus from teachers to learners where learners would be taking the lead in the discussions in the teaching and learning process.

2.3.2.1 Advantages of the Learner-Centred Teaching Strategy

Moreover, Huba and Freed (2000) indicated that the learner-centred teaching (LCT) instructions strategy has the advantage of learners constructing their own knowledge through collecting and simplifying information and integrating it with the general skills of inquiry, communication, critical thinking, and problem-solving. These authors further emphasized that the LCT instructional strategy has the advantage of actively involving learners in the teaching and learning process. Moreover, the strategic emphasis on using and communicating knowledge efficiently to address evolving issues and problems in real-world situations is yet another advantage (Huba& Freed, 2000). Finally, according to Huba and Freed (2000), one of the significances of the LCT

instructional strategy is that the teacher only performs the role of facilitating the learning process and the teacher and students together evaluate the learning.

2.3.2.2 Disadvantages of the Learner-Centred Teaching Strategy

However, contrary to the views of Huba and Freed (2000), Alsardary and Blumberg (2009) argue that learner-centred teaching instructional strategies are time-consuming and not suitable for large classes. Examples of the learner-centred teaching instructional strategies include; the problem-based learning (PBL) strategy, the project-based learning strategy, the inquiry-based learning strategy, hands-on group study etc.

2.3.3 The inquiry-based learning (IBL) strategy

The inquiry strategy of teaching is a student-centred approach to teaching and learning physics, which focuses on asking questions, seeking the truth, information or knowledge (Hwang, Chiu & Chen 2015). They further explained that inquiry-based learning is a form of active learning that begins with posing questions, problems or scenarios rather than simply presenting established facts or portraying a smooth path to knowledge (Hwang et al., 2015; Dostál & Gregar, 2015). Similarly, Savery (2015) holds that the inquiry process emphasises the fact that students need to go beyond gathering data and information to moving towards the generation of useful and applicable knowledge. In inquiry learning, the teacher acts as a facilitator provoking students' learning. It is furthermore noted that, in inquiry learning, the students or inquirers work in small groups to identify and research issues and questions to develop their own knowledge or solutions (Dostál & Gregar, 2015).

2.3.3.1 Processes of Inquiry-Based Learning (IBL)

The processes of inquiry-based learning outline the steps to follow when using the inquiry-based learning. Kampa, Vilina, Jackson, and Sileci (2016) point out that the inquiry-based learning process includes the following:

Start with a big question:

Inquiry-based learning starts with an open-ended question which has many possible solutions. The question acts as a catalyst to stir students to think deeply about the concept.

Determine what students already know:

The teacher needs to get students to determine what they know about the question or the problem. Students stay in their small groups to discuss and record what they know about the concept from their experience. As students become more experienced in explaining what they know, their productive skills grow.

Establish what students want to know:

At this stage, teachers must be smart enough to elicit a question from students that will make them wonder about the world. They must be able to tell what they want to know in a group discussion and record in the K – what I Know, W – what I Want to know and L – what I Learned (KWL) chart.

Embark on discovery in the learning process:

Teachers must guide students and engage them in a discovery process to find solutions to their questions. Students become motivated when they find answers to their questions with a strong purpose to read and listen more.

Find out what students have learned:

Students finally discuss what they have learned in small groups and later as a whole class after the discovery phase of the process. As students discuss and write down what they have learned, they use their productive skills of reasoning.

Table 2.1: KWL chart for recording progress during inquiry-based learning

KWL CHART TOPIC_____		
WHAT I KNOW	WHAT I WANT TO KNOW	WHAT I LEARNED

Kampa, Vilina, Jackson, and Sileci, 2016 – adopted and used

The researcher chooses to study problem-based learning (PBL) and not the inquiry-based learning because the IBL has been applied and used for all levels, especially for early educational levels, but on the other hand, PBL is mostly used for higher degree classes. Hence the researcher decided to study PBL at the high school level to determine the experiences of physics teachers when applying the strategy in their classrooms, their successes and challenges during their implementation thereof.

2.3.3.2 Similarities between IBL and PBL

Inquiry-based learning and problem-based learning (PBL) have certain characteristics in common which include the following (Hwang et al., 2015; Dostál&Gregar, 2015; Savery, 2015):

1. They are both student-centred pedagogy
2. They both start with a question or problem
3. They both promote the development of 21st-century skills such as problem-solving, collaboration etc.
4. In both cases, students work in small groups and the teacher acts as a facilitator, provoking student learning
5. In both cases, students develop their own learning through researching an issue or question

2.3.3.3 Differences between IBL and PBL

Even though the two approaches are similar in some respects there are quite a number of differences (Oğuz Ünver & Arabacioğlu, 2011). Table 2.2 below shows some of the differences.

Table 2.2: Differences between IBL and PBL

Inquiry-Based Learning (IBL)	Problem-Based Learning (PBL)
IBL is driven on questions based on real observation	PBL focus on solutions to ill-structured problem
IBL is based on acquiring knowledge from direct observations by using deductive questions	PBL is based on maximizing learning with investigating, explaining, and resolving real and meaningful problems
IBL is the best learning approach for human nature	PBL is the best outcome for learning and problem solving
In IBL the teacher is a leader, coach, model, facilitator, a source of driving questions	In PBL the teacher only acts as a facilitator and coach rather than a leader
The role of the student in IBL is to interpret, explain, hypothesize, design and direct own tasks	The role of the student in PBL is to determine whether a problem exists, creating an exact statement of the problem, identify information, data, and learning goals, creating a working plan.
IBL is applied to all fields, but especially for elementary schools.	PBL is also applied to all fields but is especially used for medical education, law and similar fields, which include case studies
IBL is used for all levels, but especially for early educational levels	PBL is also used for all levels; it is especially used for higher degree classes.
The specific outcome for IBL includes creativity, intelligence, conceptual understanding of scientific principles, comprehension of the nature of scientific inquiry and a grasp of applications of scientific knowledge to societal and personal issues,	Specific outcomes of PBL include effective problem-solving skills, self-directed learning skills, lifelong learning, and effective collaborations

2.3.4 Outcome-based education and Problem-Based Learning

Outcomes-based education is a common sense approach to teaching and learning whose focal point is on what the student is to learned (the outcome) (Kudlas 1994, p.32). The outcome also described as the Critical Outcome advocates that students should be able to recognize and solve problems and make decisions using critical and creative thinking skills (Department of Education (DoE), 2002). Kudlas (1994) explains that an outcome is a demonstration of learning which describes what the student is supposed to be acquainted with or execute. Other researchers defined outcome as an excellent finish display by students at the end of a learning experience and must be real, able to be seen and noticeable demonstration (Spady, 1994). By demonstration refers to occurring in real-life situation as in the case of PBL. This therefore suggests that in OBE, students leave school demonstrating mastery ability of a particular critical outcome attainment.

2.3.4.1 Similarities between OBE and PBL

Outcomes-based education can be compared to problem-based learning. Like problem-based learning, in outcome-based education, students are not immersed in information but they are taught to be critical, analytical and reflective thinkers as well as problem solvers (Barnes, 2005). This however indicates that OBE is not only student-centred, but also results-oriented for the reason that it is based on the assumption that all people can learn (Department of Education, 2002). Furthermore like the PBL strategy, the OBE focus on learning by doing, and students must demonstrate what they have learned (Christie, 1999). Another feature of outcome-based education that makes it similar to problem-based learning is that it is devoid of rote learning by memorising facts with less understanding and one short examination-oriented style. Each student is assessed individually in the case of OBE and in group in the case of PBL to determine whether learning outcome is mastered and student ready for next lesson (Laubser, 1997).

2.3.4.2 Differences between OBE and PBL

Generally, it is evident that the objective of OBE and PBL is to develop critical thinking and problem solving skills. However, in practices, things are done differently to achieve these common goals.

Table 2.3: Differences between OBE and PBL

Outcome-Based Education	Problem-Based Learning
OBE is student-centred and promote the fact that all students can achieve in the circumstance that they are given sufficient period to do so	PBL is also student-centred and promote the fact that all students can achieve in by working in small collaborative groups
In OBE students' put much effort toward what is being learnt and are familiar with the results of their study in advance.	In PBL students' put much effort toward what is being learnt and would have to research and come out with finding and present in class
In OBE, Students are given multiple chances to demonstrate that they have reached the outcome or the learning objective. the	In the case of PBL students are expected to repeat their investigations if information after the research stage is not enough to addressed the ill-structured problem.
In OBE students' advancement are based on demonstrations	In PBL students would have to do presentations in class to demonstrate what they have learned.
In OBE students' achievement is not measured against other students' achievements but only as to whether the individual student has achieved a predetermined outcome.	In PBL students achievements are measured as the effort of all the members in a group.

2.3.5 Problem-based learning versus Project-Based Learning

Project-based learning is a constructivist approach to teaching and learning that emphasizes inquiry-based active learning which takes place through collaboration in small groups and active interaction which results in valuable outcomes, meaningful to the learners as well as to the society (Krajcik, McNeill, &Reiser, 2008). The constructivist approach to Project-based learning is rooted in the fact that learning becomes more meaningful to students when they are actively involved in constructing their own learning by engaging in an authentic and meaningful task that emulates what scientists do in real-life situations.

The main characteristics of Project-based learning are that it is central to the curriculum; it is long-term inquiry-based learning driven by meaningful and authentic questions; it is autonomous; it encourages collaborative learning; and finally ends with a well-designed product (Roessingh & Chambers, 2011). In practice, in a project-based learning classroom, learners are first presented with a driving question, they work in small groups to come up with learning goals that address the driving question and engage in scientific practices to explore the driving question. Furthermore, learners engage in collaborative activities with the community and other stakeholders to find solutions to driving questions. In some cases, learners use technology to solve problems beyond their ability and finally, create a set of tangible products that address the driving question (Blumenfeld et al., 1991; Krajcik & Czerniak, 2014).

Barrows and Tamblyn (1980) define problem-based learning (PBL) as learning that results from the process of working towards the understanding of a resolution of a problem. They describe a problem as a situation that cannot be resolved with the current level of knowledge. Again, they noted that the problem in problem-based learning (PBL) must be ill-structured, such that learners could identify learning issues that are related to real-life situations, authentic and meaningful to the learner (Barrows & Tamblyn, 1980).

Operationally, in a problem-based learning (PBL) class, students are presented with a problem at the start of a lesson; they discuss the problem in small groups, define what the problem is, brainstorm the problem to identify a learning issue, reason

through the problem and indicate plans to resolve the problem (Savery, 2015). Learners come back to a problem-based learning (PBL) class and share information collaboratively with peers and work together to resolve the problem. Finally, they discuss and present the solutions to the problem (Savery, 2015).

Furthermore, it is noted that Project-based learning is like problem-based learning (PBL) in that in both cases, learners take charge of their own learning by being actively involved in constructing their own learning. But, while learners in project-based learning classrooms must produce a tangible product that addresses a driving question, learners in problem-based learning (PBL) classrooms discuss and present their solutions to the problem they worked on. Again, while in project-based learning lessons are presented with a driven question, in problem-based learning (PBL) lessons are introduced with an ill-structured problem. The choice between the two strategies, therefore, depends on the subject and the topic to be taught.

In physics, some topics could be best taught using project-based learning while others best fit the problem-based learning (PBL) strategy. While a lesson in magnetism example types of magnets can be used to teach successfully using the problem-based learning (PBL) approach. In a lesson on light, the pinhole camera can be used by the teacher using the project-based learning approach since the latter could demand that learners construct a pinhole camera and the former will expect learners to present and report findings.

Table 2.4: Summary of project-based vs. problem-based learning

Project-Based Learning	Problem-Based Learning
is driven by a driving question	is driven by an ill-structured problem
encourages collaborative learning	encourages collaborative learning
ends with an artifact to represent the driven question	ends with students reporting and present their findings
works in small groups	works in small groups
engage in exploration to answer the driven question	engages in research to answer the ill-structured problem
learning is situated in a real-life situation to resolve the driven question	learning is situated in a real-life situation to resolve the ill-structured problem

Finally, it must be noted that the acronym *PBL* is used interchangeably to refer to project-based learning and problem-based learning, but for purposes of this study, PBL will be used to refer to problem-based learning (PBL) since the study is based on problem-based learning.

2.4 PROBLEM-BASED LEARNING

Different researchers in problem-based learning (PBL) have viewed the concept differently. However, the different views may perhaps depend on the approach in introducing the concept, the subject area being considered as well as the stage of the learners whether at a university, post-secondary, high school or elementary school setting (Savery, 2015). The various views of PBL give rise to the fact that they lack uniformity (Merritt, Lee, Rilero, & Kinach, 2017).

2.4.1 Clinical perspective of problem-based learning

In the medical school, PBL is well thought-out to incorporate multidisciplinary system-based courses rather than discipline-specific ones. This means that the clinical perspective of PBL encompasses disciplines that are integrated with health sciences. Typically, students might study biochemistry with the thoughts that it is connected to appendage systems of human being, but they will end up solving problems offered in medical cases (Barral & Buck, 2013). Research has proven that medical students who are taught by this strategy excel in their academic performance (Blumenfeld et al., 1991; Krajcik & Czerniak, 2014). The strategy offers significance, enhances self-directed study, aims at higher-order thinking and engages learners in conducts with the purpose of providing improved long-term retention of content. In the clinical-medicine definition the key student skills that are encouraged are self-directed learning, reflection and teamwork (Barral & Buck, 2013).

Clinically, as Barral and Buck, (2013), explains, PBL is a student-centred instructional strategy, which uses structured clinical issues as a challenge intended for students to describe their knowledge requirements, carry out self-directed investigation, incorporate theory and practices, as well as relate knowledge and skills to build up answers to a defined clinical issue. This means that ‘Problem’ as in clinical medicine

perspective of PBL is expected to be structured. However, in such a structured problem, students are required to work enthusiastically and collaboratively in small groups to explore, create questions, get together information, and carry out investigation essential to determine solution to the problem. Dewey's principle reflects the clinical-medicine view of PBL that situates PBL in 'learning by doing' (Dewey, 1938).

Problem-based learning (PBL) is therefore entrenched in Dewey's learning by means of action and experiencing. Dewey established that students will not learn or know a concept if they do not enthusiastically engage in experimenting that about which they wish to acquire knowledge.

2.4.2 Problem-based learning versus teacher-centred teaching strategy

Problem-based learning (PBL) is quite dissimilar from conventional teaching practices such that it provides knowledge that is more real. Traditional education is time and again categorized with providing students with the required fundamental knowledge and then they recall and retrieve the information to solve problems (Allen, Donham, & Bernhardt, 2011). Jonassen (2011) described PBL, contrast to the conventional instruction strategy, as follows:

> *Traditional models of instruction assume that students must master content before applying what they have learned in order to solve a problem. Problem-based learning reverses that order and assumes that students will master content while solving a meaningful problem. The problem to be solved should be engaging but should also address the curricular issues required by the curriculum* (p. 101).

Normally, during conventional teaching and learning in physics, students for example are provided with the formula for motion during a lecture and must apply it in a word problem or a computer simulation. However, during PBL teaching and learning, teachers will for instance provide learners with a ball bearing, a launch mechanism and a target in a specific location and tell the students to hit the target consistently no matter where their launch mechanism is situated in the room. The students would have

to research the formula for motion and its applications, measure the physical properties of the ball bearing, and then devise a system to determine the correct setting for the launch mechanism based on its distance from the target. In this case, learning becomes situated, authentic, connects academic situations to real-life experience and places the student at the centre of the learning process. When learning is situated and connected to real-life experience, it turns to motivate learners to learn on their own, improve understanding and concepts learned are retained longer (Moskovsky, Alrabi, Paolini, &Ratcheva, 2013).

McParland, Noble, and Livingston (2004) explain that the PBL strategy differs from the traditional instructional strategy such, that while the curriculum in PBL is described as experienced, that of the traditional instruction is described as prescribed or pre-determined. Furthermore, they indicated that the learning environment in PBL is flexible and leaves room for learners to explore while the traditional instruction classroom is structured with less or no room for exploring. Moreover, in the PBL class, learning is constructive with opportunities to make changes and reconstruct, but in the traditional classroom settings, learning comes as a result of receiving and memorising (McParland et al., 2004). Finally, in a PBL class, teaching is done by coaching and facilitating while in the traditional learning environment it is by transmission (McParland et al., 2004).

Despite these positive findings by McParland et al., (2004), teachers still feel reluctant towards the use of PBL in their science classrooms. They associated this reluctance to various national education policies.

The researcher believes that if teachers are introduced to the PBL teaching strategy they might experience the positives, and possibly may adopt it, if not wholly, side by side with the traditional instructional strategy. This research study is therefore aimed at introducing problem-based learning (PBL) to physics teachers at Entsikeni cluster, as another teaching approach to the traditional teaching approach.

2.5 'PROBLEM' AND 'LEARNING' AS IN PBL

PBL is problem.based.learning. Hence it is more important to look at what is a problem, and what is learning, in relation to PBL. From the variety of definitions of PBL it could be really established that in PBL students learn through the experience of solving 'unrestricted problem' .and it focuses on the students' reflection and reasoning to construct their own 'learning'. As has been noted by Barrows and Tamblyn (1980), PBL results from the process of working towards the understanding and resolution of a problem. This emphasises on the fact that in PBL the key concept is the resolution of a problem (Barrows & Tamblyn, 1980)

2.5.1 'Problem' In PBL

A problem is a situation that is difficult to resolve with the current level of information (Barrows & Tamblyn, 1980). They argued that starting a lesson with a problem could be quite interesting and motivating. Furthermore, they noted that when learners identify learning issues from working on a problem, it could motivate them to start engaging in research to deal with the learning issues they have recognized. Margeston (2000, p. 9) similarly argued that, in using problems to introduce a lesson, learners do not merely obtain knowledge, the answer to a problem, but as well know what the problems are that provided the knowledge in question.

Furthermore, Barrows (1996) noted that a problem in problem-based learning (PBL) have to be ill-structured or structured, simple or complex. In addition, Barrows (1996) stressed that most PBL lessons use an ill-structured problem. The characteristics of an ill-structured problem in PBL are that it must be based on a real-life situation; authentic and such that it lacks certain information for its resolution but leads to learning issues (Barrows, 1996; Margeston, 2001). Other researchers argued that problems that are fairly ill-structured and somewhat higher than average in complexity are more likely to be successful in PBL programs (Walker, Leary, Hmelo-Silver & Ertmer, 2015)

Also, as formulated by Barrett (2010), problems can be presented to learners in various ways: scenarios, puzzles, diagrams, dialogues, case-based, quotations,

cartoons, posters, poems, physical objects, video-clips. It is further noted that the different methods of presenting problems to learners may depend on the age of the learners or on the topic being addressed. Research has shown that problems presented to learners in secondary or high schools should be a scenario or case-based problem, consequently identifying a problem from a known background will be well thought-out by learners to be more important (Barrett, 2010; Araz & Sungur, 2007).

When learners are presented with a scenario or case-based ill-structured problem in a PBL class, they are made to brainstorm, work towards understanding and resolving the problem, as well as generating information connected to the problems to recognize learning issues concerned with the cases (Araz&Sungur, 2007). In conclusion, this is the focal point of PBL; learning by doing, learners constructing and re-constructing own knowledge, learning by applying fresh information to fresh conditions (Colley, 2008; Singer, Marx, Krajcik, & Clay-Chambers, 2000).

2.5.1.1 Requirements for a problem when using problem-based learning

Writing a PBL problem is unlike writing a problem for an assignment. Nevertheless, the task is easier if the PBL teacher bears in mind the necessary requirement of a PBL problem. Barrett, and Moore, (2010) and Barrett (2010) explained that a good problem in problem-based learning (PBL) have to be based on real-life situations. He also emphasized that a good problem should be open-ended or guided, and this gives room for different solutions. Open-mindedness gives room for the problem to be explored from a diversity of dissimilar viewpoints so that the importance of the answer as well as the process of attainment becomes uniformly significant (Sawada, 1997).

Moreover, Barrett, and Moore, (2010) and Barrett (2010) emphasises that a good problem must have the content objectives of the topic integrated into the problems and frequently appear to form the preliminary point for problem writing. They further indicated that a PBL problem ought to think about the interests and needs of students as well as their future careers. Also, Barrett, and Moore, (2010) and Barrett (2010) added that a good problem must incorporate all members of the group to effectively solve it. This means that an efficient problem is required to connect the students

actively in order to give confidence and support profound height of thinking and understanding (Sawada, 1997). Finally, Barrett, and Moore, (2010) and Barrett (2010), indicated that a good problem requires that students make decisions or judgments based on evidence as well as information obtained from various information sources they used for the duration of their study. This means that the problem should be multi-staged. However, if the problem is multi-staged, it will give confidence to students to think more deeply and to explore valid assumptions relating to the physical world.

2.5.1.2 Differences between an open-ended and guided problem

An open-ended problem is a problem that has more than a few correct answers and several ways of finding the correct answer(s) (Shimada & Becker, 1997). Students contribute more enthusiastically and willingly in lessons and express their thoughts more often. Sawada (1997) explains that it has the advantage of creating opportunities for students to make complete utilization of their mathematical facts and skills. He further indicated that it provides students with a reasoning experience. This occurs by comparing as well as discussing in the classroom where students are inherently aggravated to offer reasons for their solutions to other students (Sawada, 1997). For instance, when teaching force and motion in grade 10, a teacher may pose an open-ended question such as: observe how forces such as gravity, friction, equal forces, unequal forces and change in direction cause marbles to move. Small groups build up and present models to give details the forces they study.

However, unlike open-ended questions, in a guided problem, the teacher provides a problem for enquiry as well as the essential resources and direction. The students are usually expected to work out their personal process towards resolving the problem. In fact, the difference is that the latter is given minimum guidance and support while the former is open with no guidance. Depending on the situation, the teacher needs to make an informed decision about which needs to be used.

2.5.2 'Learning' in PBL

In general, researchers in educational psychology view learning as a step-by-step procedure within which a person experiences stable or lasting change in knowledge or performance (Tomporowski, McCullick, Pendleton, & Pesce, 2015). Moreover, in relation to PBL, it is when learners follow their learning in a manner that they gain a realistic sense of why certain problems exist and why it is significant to give good reason for investigation into them, how this inquiry proceeds as well as how to assess the knowledge obtained during the investigation (Margeston, 2001, p. 9).

Furthermore, PBL is problem-based learning, not problem-based teaching. In this view, it is learner-centred and as such, it fits into a learning model, not a teaching model (Barrett, 2001). Barrett (2001) argues that the teachers using PBL are concerned about how and what students learn and not how and what they themselves teach and as such observe, supervise, listen, stimulate and provoke learners' learning. The learning of the student therefore is the central focus in PBL and not the teaching by the teacher.

Research has shown that in a PBL class the students are accountable for their personal learning (Bell, 2010). They are made to formulate authentic themes, state hypotheses, search for relevant information, plan an inquiry, collect data, discuss data with groups, present and share ideas, reason and make decisions, and develop a product (Linn, Clark, & Slotta, 2003; Songer, Lee, & McDonald, 2003). This, therefore, confirms that students are in charge for their personal training in PBL and this induces motivation as well as self-directed learning. Dolmans & Schmidt (2010) explained that PBL lesson is a dynamic development during which the student is at the core of accessing previous information, building relations among previous and recent concept and by means of explanation of relationships to connect theory building.

2.6 ASSESSMENT IN PROBLEM-BASED LEARNING

The teacher following a PBL approach has a minimum of three fundamentally broad areas to assess students as opposed to the traditional instructional strategy (McParland et al., 2004). In the first instance, PBL students are assessed on applied competencies, where they are expected to demonstrate mastery of how to organize a concept, analyse variables and identify a learning issue. Secondly, in the PBL class

students are assessed on their critical thinking skills, problem-solving skills, as well as communicative competence. Finally, PBL students are assessed on their collaborative and leadership competency. The PBL strategy, as a learner-centred strategy; therefore, uses an assessment that caters for all students in the knowledge developments process and deals with the holistic development of the students. Dos Santos (2017) elaborates: various assessment applications occur in PBL. Using the PBL strategy has assessment implications. Various assessment strategies may exist for assessing the three fundamental areas (Dos Santos, 2017).

2.7 ADVANTAGES OF USING PBL IN THE CLASSROOM

Problem-based learning (PBL) has been introduced as an instructional strategy within the post-secondary level for reasons such as improving problem-solving skills, longer retention of concepts learned, and motivation. In addition, PBL as a learner-centred approach has a lot of benefits and are discussed in the subsections that follow (Barrett, 2010, p. 165-174):

2.7.1 Conceptual understanding of subject matter content

During problem-based learning (PBL) lessons, students build up meaningful learning experience as well as deeper levels of understanding when they engage in problems in a real-life situation (Akçay, 2009). Moreover, Wong and Day (2009) recommended that in view of the fact that PBL depends greatly on constructivism and not simply memorising information; students may well develop an improved conceptual understanding.

2.7.2 Critical thinking skills and ability

Savery (2015) points out that if education in science are learner-centred like in PBL, it turns to develop students critical thinking skills and ensures lifelong learning. PBL is able to assist in reinforcing academic skills, improve critical thinking skills and teamwork spirit in students (Barrett, 2010).

2.7.3 Problem-solving skills

Akçay (2009) noted that in a PBL classroom, the teacher acts like a guide and a catalyst while students build and rebuild their personal understanding all the way through teamwork as well as problem-solving. In addition, it is emphasised that students who take on PBL activities build up stronger problem-solving skills (Akcay, 2009). Similarly, in a PBL lesson, self-directed investigation and social interaction enhance academic attainment along with improvement of problem-solving skills (Eggen & Kauchak, 2006).

2.7.4 Self-directed learning

Motivation, engagement as well as self-directed learning are enhanced when applying the PBL strategy once learners realise that they are in charge for their own education (Hmelo-Silver, 2004). Through authentic learning experience, students can construct their own knowledge (Akçay, 2009).

2.7.5 Collaboration

Learners' learning skills such like interpersonal as well as communication are enhanced by working in groups (Akçay, 2009). In a PBL lesson, information-seeking skills collaborative skills and presentation skills are improved once students get busy in communicating their ideas with others (Akçay, 2009).

2.7.6 Positive attitude, interest and motivation

While students are occupied during their learning development and discover the learning important to their lives, they are motivated and more likely to achieve educational victory (Allen, Donham, & Bernhardt, 2011).

2.7.7 Retention ability

In a PBL lesson, students learn by doing, and as a result, concepts learned are retained longer and as such improves learners' retention ability (Akçay, 2009). Students are involved in authentic activities and as such learning is retained much longer with the PBL strategy compared to the traditional lecture instruction (Norman & Schmidt, 2000). Wong and Day (2009) recommended that because PBL depends greatly on constructivism, learning is retained much longer and subsequently allows for better retention. One of the skills that are essential in PBL is lifelong learning (Allen, Donham, & Bernhardt, 2011).

2.7.8 Relevance of working together, friendships and belongingness

Learning in groups enhances teamwork and sharpens research skills (Allen et al., 2011). They also suggested that writing skills are developed through compiling finished work and reporting on it. When students work in groups, they could develop friendship and belongingness.

Despite the many advantages and successes of the PBL strategy discussed above several challenges occur that hinder the effective application of the strategy (Kolmos, 2017). The next section discusses the challenges identified by different researchers in the application of the PBL strategy.

2.8 CHALLENGES OF PROBLEM-BASED LEARNING (PBL)IN THE CLASSROOM

PBL is a holistic approach to education and involves a complete curriculum reform. Barrows and Tamblyn (1980) pointed out that it requires an intensive curriculum shift as well as support from both management and teaching staff. Kemp (2011), states that the adjustment to PBL need implicit and explicit commitments to the technique in terms of stages, roles as well as evaluation procedures. Several factors hinder successful implementation of PBL in science education in schools (Barron et al., 1998; Inel & Balim, 2010; Akınoğlu & Tandoğan, 2007). These include:

2.8.1 Potential poorer performance on tests

Problem-based learning (PBL) may lead to poor performance in South African schools where students take standardized tests since they may not cover all topics needed to make a higher score in common provincial examinations. This stems from the fact that, in problem-based learning, assessments are based on skills development, whereas in the traditional lecture system, standardized assessment is required which focuses on facts-based learning (Kolmos, 2017).

2.8.2 Reviewing a curriculum is often lacking

A general idea of the complete programme of study is required to implement the PBL strategy, but this is often lacking (Kolmos, 2017, p. 6). He further indicated that when students are being introduced to a PBL programme of study designed for the first time, it is significant to begin them with project management as well as collaborative learning so that students learning of skills in these areas can be transferred to PBL skills development. It may not be easy to revolutionize to PBL once students, teachers, as well as education staffs are products of didactic teaching methods (Walton & Mathews, 1989). In general, there is always little time to create new curricula.

2.8.3 Students' unpreparedness

While many students may feel engaged and busy with their work during PBL lesson, others may feel disengaged (Kolmos, 2017). He further suggested that the reason for students' disengagement could be attributed to lack of maturity to engage in group activities, students' unfamiliarity with open-ended problems (Brush, &Saye, 2000) and lack of prerequisite knowledge (Brush & Saye, 2000; Oliver & Hannafin, 2000). Kolmos (2017, p. 7) continues by saying that students may occasionally experience the additional workload as pressing, as they become greatly occupied and busy with PBL activities.

2.8.4 Teacher unpreparedness

Inadequate theoretical and practical knowledge of teachers in organizing the PBL class remains a major challenge (Kolmos, 2017). To this end, teachers must be given continuous proficient growth towards furnishing them by means of the necessary skills to run a good PBL class.

Sometimes since the PBL programs are not universally accepted by the entire curriculum, instability of the academic staff may exist (Kolmos, 2017). Students may be taught with PBL strategy by their grade 10 teacher but as they move to grade 11, a different teacher may come with a different strategy. Kolmos (2017) cautions that an individual instructor decides on his or her personal teaching strategy and if that instructor is no more at post, there is no stability towards maintaining the PBL strategy in the organization.

2.8.5 Time-consuming

The time frame to complete a PBL module is often limited, such that it is not likely to study the added value of PBL such as the PBL skills (Kolmos, 2017, p. 6). For example, in South African high schools, Physical Science is given four hours per week and by such a timeframe, it is impossible to learn the added value of PBL such as the problem-solving skills and formation of collaborative skills (Kolmos, 2017).

2.8.6 Inadequate material resources

Research has affirmed that appropriate resources are the turning point to the effective implementation of any science teaching strategy such as the PBL strategy (Mudulia, 2012, p. 531). Idiaghe (2004), made it clear that the accessibility of resources leads to educational productivity. This was affirmed by a study that determined the association concerning resource accessibility as well as educational efficiency. Students in schools that are well-resourced tend to show high academic performance compared to those in poorly resourced schools (Idiaghe, 2004).

2.9 THE TEACHER'S ROLE IN THE PBL CLASSROOM

Generally, the intention of a physics teacher using the PBL strategy in education is to improve the performance of students through problem-solving, critical thinking and self-motivation. In this regard, in a PBL class, the teacher directs learners to realise inconsistencies in their thoughts and to think about alternatives devoid of telling them precisely the answer (Surif, Ibrahimb, & Mokhtarc, 2013). In so doing, it encourages problem-solving among learners. However, for the teacher to promote problem-solving skills through PBL, the teacher needs to perform the duties of:

1. observing,
2. supervising,
3. listening,
4. stimulating, and
5. Provoking learners' learning.

For teachers to ensure a successful PBL class, the teacher must ensure the active involvement of students while he maintains his/her role as a cognitive coach (Colburn, 2000). When that is done, the teacher will become accustomed to the dynamic nature of PBL. Similarly, Torp and Sage (2002) explained that, in introducing a PBL lesson, the teacher needs to fulfil the following roles:

1. participate with learners in the PBL inquiry
2. maintain dual roles as a participant in the investigation and as a cognitive coach
3. monitor and coach learners' thinking

Practically, Colburn (2000) explained that the teacher using PBL has five identifiable behaviours that need to be exhibited to help develop in learners this problem-solving skill. Educators in PBL classes must:

1. Ask unrestricted questions
2. Wait for the students to respond to those questions and give them time to process

3. Repeat or paraphrase students' ideas, but do not criticize
4. Do not tell the students exactly how to do something
5. Manage discipline/behavioural problems, as always

In summary, the teacher in a PBL class has a minimum of five duties, three roles and five behaviours that need to be executed to guarantee the smooth organization of the PBL procedure. For the transition from the traditional lecture instructional strategy to the PBL strategy to be successful, it requires enthusiastic teachers, organization hold up as well as efficient operational group. However, this can sometimes confirm not easy. Teachers as well as management must therefore commit themselves to ensure this important transition.

However, teachers cannot simply change from direct instruction, learners' recitation and memorising of concepts to a PBL approach without learning innovative facts regarding learners, core curriculum, pedagogy as well as evaluation procedures (Wilson & Berne, 1999). There is therefore a call for specialized growth intervention to get teachers ready in favour of this change.

2.10 PROFESSIONAL DEVELOPMENT OF EDUCATORS

Professional development is defined as 'the procedure of getting better employees skills and competencies essential to create exceptional educational results for students' (Hassel, 1999, p. 41). He further indicated that a professionally developed educator is an inspired educator, and an inspirational as well as knowledgeable educator on the whole is significant school-related feature influencing learners' education. Loucks-Horsley and Matsumoto (1999) contend that skilled improvement may be carried out in several ways: attending workshops and meetings, attending conferences and seminars, preparing papers and presentations, courses and distance learning. Informally it can occur through: conversations and discussions with others, collaborative work with colleagues, private study and reading, observation and feedbacks.

A good teacher motivates students. The quality of education of a child largely depends on the quality of his teacher. Therefore stakeholders have to pay close attention on

the way they train both new and experienced educators. A distinguished development in teaching more or less never takes place when improving teachers' skills and competencies are not attended to (Guskey, 2000, p. 4). As a result, it is important to empower the 21st-century high school physics teachers with pedagogy that will increase their competencies in using and exploring new instructional strategy in the classroom. For this reason, it is essential for teachers to be granted ongoing and regular opportunities to learn from each other in exploring new instructional methods.

2.11 THEORETICAL FRAMEWORK

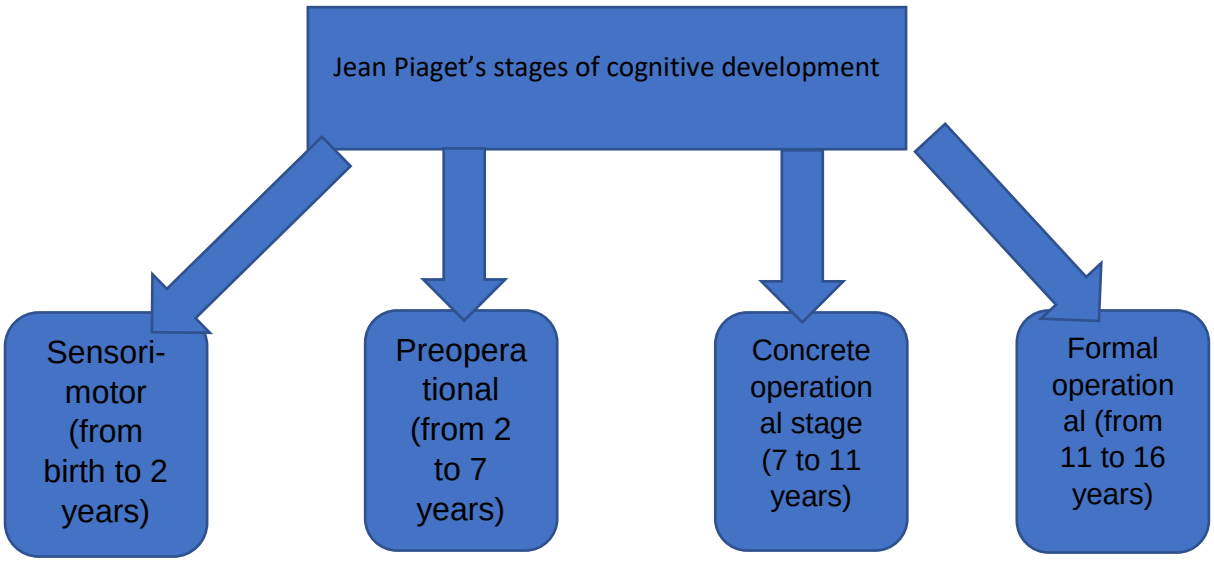
Constructivism is the theoretical and hypothetical basis that underlies the contemporary restructuring pressure group in education (Von Glasersfeld, 2013). The features of constructivism are distinct by the postulation that ‘knowledge is not transmitted directly from one knower to another but is actively built up by the learner’ (Driver, Squires, Rushworth, & Wood-Robinson, 2014; Gautam, 2018). Constructivists are of the view that knowledge must not be viewed as a measly broadcast of information, however as a conspicuously embedded and dynamic process (Lave & Wenger, 1991). They argued that learning should be situated in a precise social background along with an authentic societal and physical environment. PBL as a form of situated learning is based on the constructivist judgment that students increase understanding of material once they enthusiastically create their understandings through working with as well as using facts in real-world contexts (Greeno & Engeström, 2006; Lave & Wenger, 1991).

For instance, in a situated PBL lesson learners could be provided with two balls of clay and two tennis balls, measure the masses and allow each pair to collide at different velocities to investigate the principle of conservation of momentum. Learners extend their investigations to finding solutions to problems in real-life situations and can predict which body was moving at the highest speed, determine the factors that cause greater impact during a collision and devise a means to reduce the extent of the impact. This approach is different from the traditional physics classroom, where learners must learn the theory of momentum, use the formulae in word problems and memorise some applications of momentum in everyday life.

Brown, Collins and Duguid (1989) are convinced that, to form meaningful knowledge, ‘'knowing what'' and ‘'knowing how'' cannot be separated and that is the root of situated learning. To form a meaningful learning, students have to enthusiastically engage in the teaching and learning process, constructing as well as reconstructing their own understanding (Driver, Asoko, Leach, Scott, & Mortimer, 1994). This provides the lens through which this research could be evaluated. The researcher also looked at Jean Piaget’s cognitive development theory and its implications for learning as a lens through which to analyse and evaluate the study.

2.11.1 Jean Piaget's stages of cognitive development and its implications for teaching and learning

Piaget’s study was based on observing children as they created ideas, and enthusiastically constructing their own knowledge. Piaget's effort offers the basis on which constructivist theories are based. Constructivists believe that knowledge is constructed by students themselves and learning occurs when students come out with a product or create an artefact (Grossniklaus, Smith, & Wood, 2001). They proclaim that students are most likely to engage in learning when these products or artefacts are relevant and meaningful to them. In studying the cognitive development of children and adolescents, four major stages were identified by Jean Piaget: the sensorimotor stage, the preoperational stage, the concrete operational stage and the formal operational stage.



Piaget supposed each and every child pass through these stages as they grow and they follow these stages sequentially without skipping or jumping any of them. Teachers must have knowledge of the characteristics of these stages and how children learn at each stage to plan the learning needs of their students. For the purposes of this study, the formal operational stage and its implications for teaching and learning will be discussed since the study target students in the Further Education and Training (FET) phase.

2.11.2 Formal operational stage

This stage runs from 11 years to 16 years of age. Piaget (1952) explained that the stage is characterized by the growth of mature patterns of judgment connecting logical, rational and abstract thinking. He indicated that during this stage adolescents can think systematically about relationships between variables, devise hypotheses, as well as reflect on nonfigurative associations and concepts (Piaget, 1952). Furthermore, students at this stage can construct theories and make logical deductions (Piaget, 1952). Piaget trusts that the construction of knowledge at this stage is facilitated through co-operation with peers. He observes that as far as the growth of intelligence is concerned, students must co-operation and collaborate with peers. Piaget (1950) explained that co-operation is the first of a series of forms of behaviour which are vital for the formation and development of common sense.

Students generally at this stage are curious and are able to contract with abstractions as well as psychologically investigate similarities and differences (Piaget, 1952). According to Joubish and Khurram (2011), teachers should take advantage of students' curiosity by introducing interesting puzzles or problems rather than boring drills.

2.11.3 Teaching the Formal Operational Students

This stage is characterized by abstract thinking and the content of instruction must aim at helping the student to deal with abstractions. Piaget (1952) emphasised that content of teaching requires to be consistent with the developmental level of the student.

2.11.3.1 Instructor's responsibility and responsibility for learning

At the formal operational stage, the instructor's responsibility is to smooth the progress of learning by providing diversity of experiences (Piaget, 1952). Research is consistent with the constructivist view that teachers are facilitators of students learning as they construct and reconstruct their own understanding (Crawford, 2000, p. 918). Whereas a teacher gives a lecture to cover up a topic, a facilitator assists students in gaining their own understanding of content. According to the social constructivists, instructors must become accustomed to the responsibility of being facilitators and not teachers (Bauersfeld, 2012). The emphasis changes from teacher and content delivery, to the student and own content building (Crawford, 2000).

In view of this, the responsibility of learning is therefore the sole duty of the students as they persevere to build and rebuild their own concept (Von Glasersfeld, 2013). Subsequently, this suggests that the student must determine what the word 'learn' means in consistent with constructivist view (Savery & Duffy, 1995). Social constructivism consequently emphasizes the significance of students being enthusiastically involved in the learning process and therefore being responsible for their own learning (Siemens, 2014). Students look for meanings and construct their understanding yet in the absence of absolute information, they do not have to simply imitate what they have read or are told (Von Glasersfeld, 2013).

2.11.3.2 Students' prior knowledge

In teaching the formal operational students, Beard (2013) suggested that learning should begin with concrete experiences or students' own experiences to abstractions. This emphasises the importance of students' prior knowledge (Driver, Squires, Rushworth & Wood-Robinson, 2014). Constructivists believes that previous information impacts on the learning process (Driver et al., 2014; Gautam, 2018) and emphasised that information not connected to students' prior knowledge would perhaps be quickly forgotten. They therefore suggest that teachers must tap on students' previous knowledge and students have to enthusiastically build innovative information from an active intellectual framework for significant learning to take place. Piaget argued, and affirmed by Joubish and Khurram (2011), that teaching students at this stage must begin with introducing them to real-world phenomena, from concrete considerations up to more nonfigurative way of thinking. This captures their enthusiasm as well as build on previous successes to improve their self-confidence in the concept under discussion (Brownstein, 2001). Hence the link with Vygotsky's zone of proximal development, which described the distance between the actual developmental level (independent problem-solving) and the level of potential development (problem-solving under guidance of or collaboration with peers) (Vygotsky, 1978).

2.11.3.3 The learning environment

Piaget (1952) explained and consistent with the views of Joubish and Khurram (2011), that for assimilating new information the teacher should use familiar examples from real-life situations to assist in explaining more complex ideas. Constructivists support the view that knowledge is synthesized and prearranged within the background of a dilemma in a real-life situation (Crawford, 2000). As a result, the understanding of a concept is reliant on connections with the learning environment.

Several researchers are of the view that students at this stage must interact with ill-structured problems relating to their immediate environment for cognitive loading and assimilation (Joubish & Khurram, 2011). Jonassen (1997) supports problem-solving scenarios for more advanced students. However, theorists of cognitive loading of

novices do not hold up the thought of allowing novices to work together by way of ill-structured learning environments (Paas, Renkl, & Sweller, 2004). According to them, novices must be trained with 'well-structured' learning environments. Jonassen (1997) as well wished-for well-designed and well-structured learning environments to provide support for problem-solving in novices.

Sweller and his acquaintances yet propose well-structured learning environments for those with further experience (Paas, Renkl, & Sweller, 2004). Cognitive load theorists suggest that teaching the formal operation student requires worked examples initially, with a gradual introduction of problem-solving scenarios (Renkl, Atkinson, Maier, Staley, 2002). They described the process as the guidance-fading effect.

2.11.3.4 Engaging and challenging the learner

To usefully engage as well as challenge students, the task environment and the learning situation must mirror the complexity of the environment in which a student should function at the end of learning (Derry, 1999). Since students at this stage can involve in logical and abstract thinking, it is the time when teachers can develop problem-solving skills in their students (Piaget, 1952). He indicated that students have to continuously be challenged by tasks that deal with skills and facts just above their present stage of mastery. Crawford (2000, p. 918) suggested that this could be done using inquiry-based learning and engagement in higher-order thoughts as well as problem-solving. Furthermore, since the stage is characterized by hypothetical thinking, teachers must encourage students to explore. One way is through hypothetical questions and discussions or by posing questions about social issues and the world around us (Joubish & Khurram, 2011).

Students must work in small groups during explorations. Esterberg (2002) explained that, the process of learning is through social interactions in small groups. He emphasized that working in small groups and in a social context grants students' better opportunity of finding solutions to difficult skills than when working alone. This links up with Vygotsky's 'zone of proximal development'.

2.11.3.5 Collaboration among learners

The teacher must offer time for development and involve students in activities with experienced students and other experts (Joubish & Khurram, 2011). They indicated that teachers must allow social interactions when they teach concepts; they must model formal patterns of reasoning. This suggests enthusiastic participation of students throughout the learning process and collaborations. According to Duffy and Jonassen (2013), students by way of diverse skills as well as cultural backgrounds have to work together through negotiations to arrive on mutual understanding.

Furthermore, on the whole social constructivist models emphasis the need for teamwork among learners as proposed by Duffy and Jonassen (2013). One such model is the zone of proximal development by the Vygotskian notion. This model describes the space between the real developmental stage of a student as indomitable by self-governing problem-solving and the level of potential development as determined through problem-solving in partnership with more able peers (Vygotsky, 1978)

In view of the above discussions, the constructivist approach to teaching and learning reflects the Problem-based learning (PBL) strategy. It suggests that the teacher changes from being the store of information to students to becoming a catalyst, as students build and rebuild their personal understanding during teamwork as well as pinpointing (Akçay, 2009). According to Hung (2011) and Kumar (2010) all agree: the essential features of PBL that reflect constructivism are that:

1. student-centred, independent exploratory learning occurs in a collective and collaborative background;
2. the central end of knowledge is the attainment of theoretical understanding, pinpointing skills, critical thinking skills, as well as inquiry skills to explore real-life problems; and
3. The teacher serves as a cognitive trainer in addition to being a concept catalyst.

As a result, constructivism provides the researcher with a lens through which the knowledge gained by teachers in their experience in applying the PBL strategy would be analysed. Furthermore, the lens provided could help evaluate students' learning outcomes through teachers' experiences. The constructionist lens will also assist the researcher in exploring the construction of external artefacts by students to signify the meaning of the problem they have solved. Finally, it is through these lenses that the researcher explored the experiences of physics teachers while implementing PBL in their physics classrooms.

2.12 SUMMARY OF CHAPTER

This chapter refers to as the heart of the study deal with intensive review of literature on the study. The chapter gives detailed explanations of the process of teaching and learning science as well as the different teaching strategies in science education. This led to the discussions on the advantages and disadvantages of the teacher-centred and learner-centred teaching strategies which subsequently paved way for the researcher to introduce the PBL instructional strategy. The chapter also discusses the inquiry-based learning and its relationship with the PBL strategy. 'Problem' and 'learning' as in PBL is also discussed to give in-depth knowledge on the meaning of problem-based learning. The understanding of the requirements of a problem when teachers are using the problem-based learning (PBL) strategy is also discussed. Again, the chapter focuses on detail explanation on the role of the teacher in a PBL classroom, the assessments in a PBL class, and the advantages of using the PBL strategy. Moreover, brief overview of the challenges of using the PBL strategy is also discussed. Since the adoption of a new strategy in teaching requires the training of the teacher, professional development of teachers is discussed in this chapter elaborating on how it is essential for the teacher to be developed.

The academic structure of the study is discussed in this chapter. The constructivist approach to teaching is adopted as theoretical framework that guides the study due to its connection with the PBL strategy. Finally, the Jean Piaget's stages of cognitive development and its link with the PBL strategy as well as its implications for teaching and learning are discussed. The next chapter, chapter three will focus on how data will

be collected, presented and analysed and pattern identify will be interpreted in chapter four and supported by literatures from this chapter.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 INTRODUCTION

The aim of this research is to determine what physics teachers' experiences are after having attended workshops on how to use PBL in the physics classroom. This chapter includes a discussion on the research design (see section 3.2) as well as a brief overview of the location of the study (see section 3.3). Furthermore, the sampling and sampling criteria were also discussed (see sections 3.4.1 and 3.4.2). A discussion of the various research instruments, how they were designed, how they were used to collect data for the study and their advantages and disadvantages were offered (see section 3.5). An overview of the validity and the reliability of the instruments used were presented (see section 3.6) where the level of confidence in the instruments was given. The pilot study was discussed (see section 3.7) as well as how the instrument was *altered* after the study. Data collection and data analysis procedures used were discussed (see sections 3.8 and 3.9). Finally, various research ethics considered were offered (see section 3.12).

3.2 RESEARCH DESIGN

A research design describes the methods and steps a researcher follows in gathering information about a study (McMillan & Schumacher, 2010, p. 20). It is the overall strategy that one chooses to link the different components of a research study in a comprehensible and logical manner to ensure that a research problem is addressed. It therefore includes, method of data collection, measured and analysed. This study employs a descriptive research study design.

Yin suggested three types of descriptive research study designs, namely observational, case study and survey. However, the case study research design was chosen for this study as this design is used to perform an in-depth study of an individual or group of individuals which may involve both qualitative and quantitative research methods (Jackson, 2015; Kessler & Stafford, 2008). The emphasis is on the fact that a case study research could be used for an individual, organization, event or

action at a time (Kessler & Stafford, 2008). Jackson (2015) further indicated that the case study allows for the study of a rare phenomenon but cannot be used for accurate prediction since it could occasionally be biased.

Yin (1994, p. 23) defined a case study research design to be an empirical inquiry that investigates a contemporary phenomenon within its real-life context when the boundaries between phenomenon and context are not clear and in which multiple sources of evidence are used. Nevertheless, Yin's definition fits this study in two respects; first, empirical evidence of teachers' knowledge in PBL was collected using a questionnaire and secondly, information on teachers as the context of the study was obtained at school (phenomenon within its real-life context).

In another view, Yin (1994) indicated that case studies are the preferred strategy when 'how' and 'why' questions are posed (explanatory case study). This makes it possible to study the second sub-question 'How do these physics teachers implement PBL in their classrooms? This was done using the case study design since it was posed using 'how'. Moreover, after deciding on a case study approach, it is important for a researcher to determine which type of case study to use in a research. There are two types of case study design, namely exploratory and explanatory case study (Yin, 2003). Yin (2003) noted that the choice of case study method depends on three things:

1. the type of research question posed;
2. the control a researcher has over actual behavioural events; and
3. The degree of focus on contemporary as opposed to historical events.

Consequently Yin (2003) described an exploratory research as dealing with a situation where a researcher has an idea or must observe something and wants to find out more about it (Yin, 2003). In other words, he explained that exploratory research design is used for a problem that has not been studied clearly. Moreover, he indicated that the exploratory case study design is employed as a research design if the research question focuses on 'what'. In a similar view, Saunder, Lewis, and Thornhill (2012) described exploratory case study design as a research technique used to study a new topic or a study in a new dimension and does not intend to offer conclusive evidence. They further indicated that it helps to have a better understanding of the problem.

Generally, it is the case in this study, which is aimed at making teachers aware of an alternative approach to teaching physics and to influence them to use it in their teaching.

On the other hand, explanatory research is meant to explain why events occur in order to build, elaborate on, extend or test the theory. Yin (2003) put forward that 'how' and 'why' questions are explanatory, and are likely to favour case studies, experiments or histories.

Nevertheless, it could be noted from the previous explanations that in this study a combination of descriptive case study design and exploratory case study design were used. However, this could be viewed from two different perspectives; the main research question for this study is 'what are the experiences of physics teachers when implementing problem-based learning?' This question was posed with 'what' and therefore is exploratory and favours any of the research strategies (survey, case studies, experiments or histories) (Yin, 2003). Again, the two sub-research questions: 'What are physics teachers' experiences of the use of PBL before an intervention?' and 'What are the successes and challenges of these physics teachers when using PBL in their classrooms' were posed using 'what' and are also exploratory.

In addition, Shields and Rangarjan (2013) held the contrary view and explained that the exploratory case study relies on methods such as informal qualitative approach through discussions and formal qualitative research through in-depth studies. Nevertheless, in this study, qualitative data were collected with open-ended questionnaires, interviews and lesson observations while quantitative data were obtained from the biographical data from respondents. Johnson and Christensen (2008, p. 328) argued that in a quantitative non-experimental design there is no control of conditions, variables and extraneous influences. In this study teachers' biographical data were studied using the non-experimental design but the actual study was done using a qualitative data collection and analysis technique since the study focuses on obtaining information about the experiences of some groups of teachers and not studying the relationship between variables.

Consequently, since the study collected data using two research techniques, one following the other, the exploratory design was considered the best approach. This

was based on Cresswell's (2002) argument that the exploratory design is recommended if the researcher's aim is to collect quantitative and qualitative data in sequence in a form of a mixed approach. Cresswell (2002) pointed out that the mixed-methods approach has the advantage of yielding detail information about a study, as opposed to a single approach.

As a result of the argument above, the exploratory case study research design was employed in this study since the research questions were posed with 'what' and the study covers a small geographical location and deals with issues regarding education (Gulsecen & Kubat, 2006). Gulsecen and Kubat (2006) advanced that the case study research design is the preferred approach when the study covers a small geographical location and deals with issues regarding education.

3.3 LOCATION OF THE STUDY

The study was conducted at the Entsikeni cluster in the Harry Gwala district (previously called Sisonke district) in KwaZulu-Natal, South Africa. This area was chosen as a result of poor student performance in the National Senior Certificate Examination in Physical Science (NSCE, 2015 - 2017). Another reason for choosing the district was that the researcher has been teaching physics and mathematics in the district for the past five years and thus has good geographical knowledge of the district which therefore minimizes the challenges that may be encountered when moving around to conduct the research. The map below gives the picture of the study location.

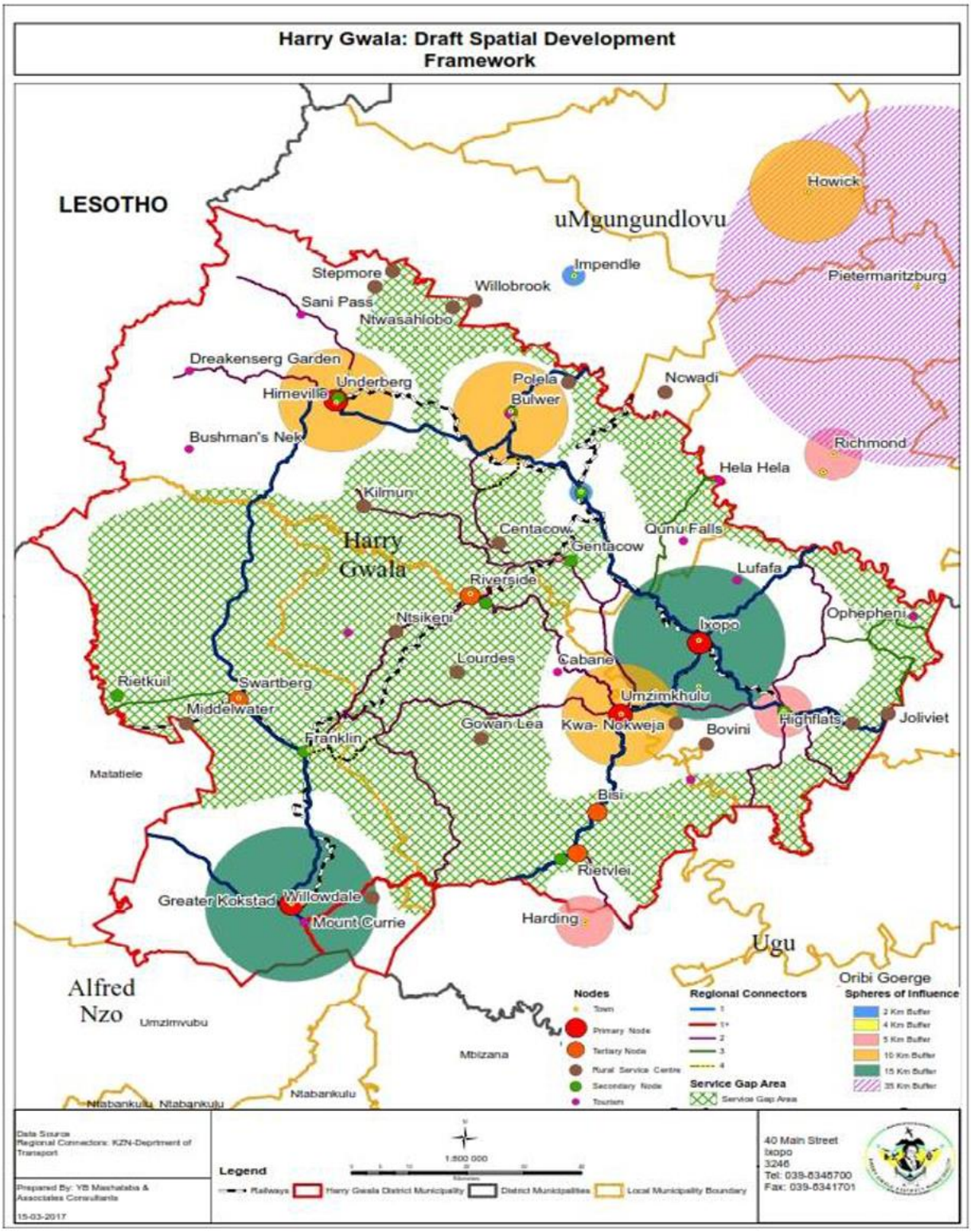


Figure 3.1: Geographical location of the study (Entsikeni)

3.4 POPULATION

A population is a group of individuals with specific norms or criteria and to which we intend to generalize the results of the research (McMillan & Schumacher, 2010, p. 119). In other words, it describes a community of animals, plants and human beings inhabiting a place. The target population is the entire group of individuals having the characteristics that the researcher is interested in (McMillan & Schumacher, 2001, p. 169; Johnson & Christensen, 2008, p. 223). Participants, also called human subjects, are persons who participate in human subject research by being a target of information by researchers. In a similar view, participants are the individuals who take part in the study, and from whom data are collected (McMillan & Schumacher, 2010).

This study targeted Physical Science teachers in 89 rural public high schools in the Harry Gwala district. The study was conducted at the Entsikane cluster in the Umzimkulu circuit.

3.4.1 Sampling

The sample is a subset of the population being studied. It represents the larger population and is used to draw inference about that population. The sample of a study therefore, indicates the participants in a study. Sampling, on the other hand, refers to a process of selecting a small portion of the population to represent the entire population for the study (Johnson & Christensen, 2008, p. 222). Sampling has also been defined as several people taken from the wider population so that a researcher can possibly make generalizations that are unbiased (Neuman, & Robson, 2007). This study was conducted at the Entsikene cluster in the Harry Gwala district in the KwaZulu-Natal province, but it was impossible to cover all the 89 high school physics teachers in the district and so eight (8) public rural high schools were selected, and 16 physics teachers were targeted as the sample space from the target population (McMillan & Schumacher, 2001).

3.4.2 Sampling criteria

The two sampling techniques normally used in educational research are the probability and non-probability sampling techniques. Probability sampling is also known as random sampling. In probability sampling, subjects are drawn from a larger population in such a manner that the probability of selecting each member of the population is known (McMillan & Schumacher, 2010, p. 127). Furthermore, every item in the universe has an equal chance of inclusion in the sample in probability sampling. McMillan and Schumacher (2010) mention that the different types of probability sampling techniques include the following: simple random sampling, systematic sampling, stratified random sampling, cluster sampling, and multistage sampling.

On the contrary, a non-probability sampling is that type of sampling technique which does not have any basis for estimating the probability that each item in the population has been included in the sample (McMillan & Schumacher, 2010). In another view, non-probability sampling, the researcher uses subjects who happen to be accessible or who may represent certain types of characteristics. The different types of non-probability sampling include convenience sampling, deliberate sampling, purposive sampling, judgment sampling and quota sampling (McMillan & Schumacher, 2010, p. 127).

Consequently, this study employs a non-probability purposive sampling technique to select the research sites or the schools. Meanwhile, it was in the researcher's interest that all the 8 high schools at the Entsikene cluster were used for the study. However, this forms 100% of high schools in Entsikene cluster but represent only 9.2% of the 89 high schools in the Harry Gwala district as it was not possible to study all the schools in the district. Consequently, all high school physics teachers from the selected schools were selected to represent the sample space for the study based on convenience.

3.4.3 Sample size

Several factors influence the determination of a sample size in a research study. However, these factors include the type of research, research question(s), financial constraints, and number of variables to study and the methods of collecting data (McMillan & Schumacher, 2001, p. 177; Johnson & Christensen 2008, p. 24). In addition, certain characteristics in the target population should be considered when deciding on the size of the sample from a population (McMillan & Schumacher, 2001; Johnson & Christensen 2008). For this reason, it was envisaged that 16 physics teachers from the 8 selected schools were used for the study. However, this sample size was adequate and large enough to do a qualitative study on the experiences of physics teachers when implementing problem-based learning (PBL) in their classrooms. Furthermore, the sampled size was also adequate to answer the research questions as well as correcting any error in terms of the provision of the data for this study.

Moreover, no distinct representation in terms of gender or grade teachers was considered. Hence, this means that in terms of sample size, the population of physics teachers in the selected schools was represented as the sample size. Anderson (1993) explained that the difference between the characteristics of the population and the sample size selected for the study is dubbed ‘sample error'. As a result, the larger the sample size, the smaller the sampling error and vice versa. Hence, this signifies that the sampling error in this study was zero in relation to public high schools at Entsikene but 90.8% in relation to the public high schools in the entire Harry Gwala district.

3.5 RESEARCH INSTRUMENTS

Research instruments are measurement tools designed to obtain data to answer a research question. The main instruments used in this research consist of open- and closed-ended questionnaires, interview protocol and classroom observations using the Reform Teaching Observation Protocol (RTOP).

3.5.1 Questionnaire

A questionnaire as research instrument consists of a series of questions for obtaining data from respondents with the objective of answering a research question. Richards and Schmidt (2002, p. 438) cautioned that questions in a questionnaire need to be constructed correctly for a study to be valid, reliable and unambiguous. On the other hand, Johnson and Christensen (2008, p. 170) described questionnaires as a self-report instrument that respondents in a research complete as part of a research study to answer a research question. They indicated that in designing a questionnaire, questions can include open-ended, closed-ended, partly open-ended or rating scale questions.

Jackson (2015), however, pointed out that although open-ended questions are difficult to analyse statistically, it allows diversity of responses from respondents as opposed to closed-ended questions, which limit respondents' views. He furthermore stated that an open-ended question allows the respondents to use their own words to answer the questions posed. As a result, open-ended questions are useful to avoid influencing respondents' responses since it does not provide a list of possible set answers to choose from. This study was meant to obtain in-depth information about teachers' experiences and as such used open-ended questions so that respondents could freely express their feelings. According to Jackson (2015), one of the characteristics of open-ended questions is that they do not require pre-coded answers. Despite the advantages, they have the disadvantage of being time-consuming, may lead to unusable information and respondents who have difficulties expressing themselves may avoid answering (Jackson, 2015).

On the contrary, closed-ended questionnaires are normally referred to as multiple-choice since they grant respondents the opportunity of choosing from a group of responses. However, these types of questions are useful, especially when one expects the respondents to provide some specific level of details (Jackson, 2015). Furthermore, it is quick to answer and easy to handle by all respondents. Seliger, Seliger, Shohamy and Shohamy (1989) believe that closed-ended questionnaires are more efficient due to their ease of analysis. Following the argument above, this research made use of closed-ended questions to collect data from respondents on

biographical information, and open-ended questions were used for obtaining data on the other research questions. The objectivity of a questionnaire as a research instrument over other instruments was the reason why it was chosen. Rowley (2014) indicated that in a questionnaire, the questions are presented on paper and there is no opportunity for biases.

3.5.1.1 Advantages of using a Questionnaire

The use of a questionnaire as a data collection instrument has an advantage over other instruments in many respects. Research has proven that the questionnaire is the most widely used technique for obtaining data from participants in research (McMillan & Schumacher, 2010, p. 195). In addition, it can easily be analysed more scientifically and objectively than other forms of research instruments (King, Meiselman & Carr, 2013). Finally, it could be used alongside other data collection methods in a research study (Johnson & Christensen, 2008, p. 170) and that was the case with this study when it was used alongside with interview protocol and Reform Teaching Observation Protocol (RTOP) to obtain in-depth knowledge on teachers' experiences in PBL.

3.5.1.2 Disadvantages of using a Questionnaire

Even though the questionnaire has a greater advantage over other instruments, it may have its own disadvantages. Respondents may skip or ignore certain questions making it difficult to analyse (McMillan & Schumacher, 2010). Again, those who have an interest in the subject may be more likely to respond, skewing the sample to either direction.

3.5.1.3 Design of the Questionnaire

The questionnaire for this research was developed taking into consideration the main research question as a guide so that the researcher will not deviate from the aim of the research. In formulating the questionnaire, questions were asked for a precise answer and leading questions that may give respondents a clue to the answer were avoided (Schober, 1992). Sometimes questions hide in dual questions when designing

a questionnaire and this was avoided. However, the questions were set to avoid double questioning and to avoid questions involving negatives so that respondents do not get confused by language (Romero & Han, 2004). Two questionnaires were developed; one was used before the intervention workshop and the other after the intervention.

3.5.1.4 Questionnaire one: Teachers' experiences before intervention

The first questionnaire referred to as Questionnaire one (1) Before Intervention (Q1BI) was labelled as part one and consisted of two sections: section A gathered information on teachers' biography and section B assessed teachers' initial knowledge and skills in PBL prior to the professional development intervention.

Section A consisted of 8 questions which focused on biographical information of respondents regarding gender, age group, overall number of years of Physical Science teaching experience, highest qualifications: academic and professional, and the subject(s) majored during the training of teachers at tertiary level. A Likert scale of 1 to 4 was used to determine the types of schools that respondents are working in. Gender was determined using a nominal scale of 1 or 2. A scale of 1 to 6 for the age group. Again, a scale of 1 to 6 was used for teaching experience. Academic qualification of teachers was scaled 1 to 11 and professional qualifications1 to 6. A scale of 1 to 8 was finally used for subjects majored at training (see Appendix C).

Section B of part one consists of 9 questions and focused on questions that assessed teachers' knowledge and skills concerning PBL. The first question of part one section B was posed to determine which approaches physics teachers use when teaching their physics learners. A Likert scale of 1 to 6 was used. However, the rest of the questions 10 to 17 were open-ended which afforded respondents the opportunity of expressing themselves freely and it was aimed at obtaining more information from respondents (see Appendix C). Table 2 indicates the structure of the questionnaire: the sections, the themes and the variables representing each item.

Table 2: Teachers' knowledge of PBL before the professional development intervention

Section	Themes	Variable
A	Biographical information	v_1, v_2, v_3, v_4, v_5, v_6, v_7,
B	Teachers' initial knowledge and skills in PBL before the professional development intervention	T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9

3.5.1.5 Questionnaire two: Teachers' experiences after the intervention

The second questionnaire referred to as Questionnaire two (2) After Intervention (Q2AI) consisted of 8 items that elicit teachers' experiences in PBL after the professional development intervention. The questions were open-ended to grant the participants the opportunity of freely expressing their level of acquisition of knowledge in PBL (see Appendix D). Table 3 indicates the structure of the second questionnaire: the sections, the theme, and the variables represent each item for easy analysis.

Table 3: Teachers' experiences after the professional development intervention of PBL

Section	Themes	Variable
A	Teachers experience after the intervention on PBL	T_{10}, T_{11}, T_{12}, T_{13}, T_{14}, T_{15}, T_{16}, T_{17}

3.5.2 Interview Protocol

An interview is a verbal conversation between two parties with the objective of collecting relevant information in the interest of research. According to Burns (2003) 'interviews are a popular and widely used means of collecting qualitative data.' Interviews are particularly useful for getting the story behind a participant's experience (Burns, 2003). Furthermore, Merriam (1998, p.71) lamented that an interview is considered the best instrument for obtaining a special kind of information about what is going on in a respondent's mind. Johnson and Turner (2003, p.308) stresses that

an interview encounter is good for measuring attitudes and most other content of interest and can provide in-depth information. As a result, this study uses an interview protocol to obtain in-depth information about physics teachers' experiences in PBL.

Moreover, it has been proven by researchers that, in research, the researcher cannot observe the respondents "feelings and thinking; interviewing is key to understand what and how people perceive and 'interpret the world around them' (Zohrabi, 2013, p. 3). This, however, means that to obtain in-depth information about how teachers think and feel about the implementation of the PBL strategy, an interview protocol was the preferred instrument.

In view of this, the interviewed questions in this research study were semi-structured with 19 items. Moreover, it comprises three themes which were selected to determine the teachers' experiences; the successes and the challenges when they implemented the PBL strategy in their respective classrooms after the professional development workshop. Thus theme 1 elicited information on the experiences of teachers before and after the implementation of the PBL strategy and consisted of seven items. Furthermore, theme 2 covered the successes in the implementation the PBL strategy in schools and consisted of four items. Finally, theme 3 touched on the challenges during the implementation of the PBL strategy and consisted of eight items. The interview protocol is attached as Appendix E.

3.5.2.1 Advantages of Interviews

The use of conducting an interview as a data collection instrument has advantages over other instruments. Gay and Diehl (1992) explained that the interviews are the preferred strategy when asking questions that deal with emotions and experiences. He further indicated that such questions cannot be put in the form of multiple-choice. Moreover, Gay and Diehl (1992) opined that during the interview section, questions asked can be reframed to suit the situation of the interview; hence making it flexible to use. Finally, he indicated that the interviewer establishes a relationship of trust with participants, such that participants may provide information, which they would not have done if a questionnaire was used.

3.5.2.2 Disadvantages of Interviews

Bailey (1994) outlined some disadvantages of an interview protocol. Bailey (1994) pointed out that following the interview method can occasionally be very costly to organize. Moreover, he indicated that Interviews can occasionally be time-consuming since it could be very lengthy. Finally, it could be noted that in an interview, participants are not easily accessible and will not avail themselves when they are busy (Bailey, 1994).

3.5.3 The Reform Teaching Observation Protocol (RTOP)

Lesson observation with physics teachers was conducted during the follow-up visit to assess teachers' successes and challenges during the implementation of the PBL pedagogy. Observation is defined as ‘an attempt to witness events as they naturally occur’ (Flick, 2018). Burns was of the same view with Flick, as per Burns (2003) when he indicated that during lesson observation, the researcher observes the ‘classroom interactions and events, as they actually occur’. This justifies that during the class observation, the data collected on the teaching method confirmed what occurs in the classroom. Merriam (1998, p. 96) believes that observation is a type of data triangulation to ‘substantiate a finding.’

The Reform Teaching Observation Protocol (RTOP) was used as the lesson observation tool (see appendix D). The Reformed Teaching Observation Protocol (RTOP) was created by the Evaluation Facilitation Group (EFG) of the Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT) (Piburn, Sawada, Turley, Falconer, Benford, Bloom & Judson, 2000). It is an observational instrument designed to measure ‘reformed’ teaching. In this study it was used to evaluate physics teachers teaching practices before being introduced to the problem-based learning teaching strategy and after being introduced to the strategy to explore a change in their teaching practices.

3.6 VALIDITY AND RELIABILITY

Joppe (2000, p. 1) defines reliability as the extent to which results are consistent over time. This indicates an accurate representation of the total population under study. When an instrument measures what it is truly meant to measure, the instrument is said to be valid. Any instrument in research for collecting data must be reliable and valid. It is therefore important for a researcher to ensure that the instrument he is about to use has undergone validity and reliability tests.

3.6.1 Validity of the questionnaires (Q1BI and Q2AI)

Validity can be checked by a panel of experts or by using another survey in the form of a field test. This research employs content and face validity to ensure that the questions in the questionnaires successfully answer the research questions. Content validity is achieved when a logical connection between the test items is estimated by gathering together a group of subject matter experts to review the test items (Joppe, 2000).

Face validity refers to the degree to which a test or assessment measures what it is meant to measure (Joppe, 2000). The questionnaires were tested in a pilot study to establish whether it measures what it is meant for and the necessary adjustments were made where necessary.

The questionnaire was sent to an expert at the department of education in Kokstad, who is a researcher and a subject advisor, to assist in establishing content and face validity of the questionnaires. A colleague studying for her PhD at the Witwatersrand University in South Africa also took part in the validation exercise. Finally, the questionnaire was sent to my supervisor who helped in the restructuring and validation of the content of the questionnaire. Upon her advice, all the closed-ended questions in the first questionnaire section B and the second questionnaire were all changed to open-ended questions to enable the researcher to gain more information from respondents.

A few examples are indicated below:

1. Would you prefer to teach your physics learners in groups?

Was restructured to:
What teaching strategy do you prefer when teaching physics lessons? Explain why you prefer this teaching strategy.

2. Did you enjoy working in groups during the workshop?

***Was changed to*:**
Briefly explain what you liked or disliked in the workshop?

3. Did your skills in formulating a driving question, and/or ill-structured problem improve during the workshop?

Was revised to:
What do you think are the requirements for a problem when you use the problem-based learning (PBL) approach, after the workshop?

The necessary corrections and adjustments were made after the validation exercise before the questionnaire was administered.

3.6.2 Reliability of the questionnaire (Q1BI and Q2AI)

Reliability is the measure of how stable, dependable, trustworthy and consistent a test measures the same thing each time it is administered (Worthen, Borg, White, 1993). After validation, the questionnaire was administered to 6 physics teachers in 3 schools in the district that were not part of the schools selected for the study, to determine the reliability of the instrument. After having analysed the results, it was found that the questions were not ambiguous and answer the research questions.

3.6.3 Validity of the Reform Teaching Observation Protocol (RTOP)

The RTOP instrument was developed in the USA and needed to be adapted for South African schools. Therefore, this instrument was distributed to 2 experienced researchers and 1 psychologist from the department of education to help assess the validity of the instrument. In addition, three (3) heads of department from the sampled schools were involved in assessing the validity of the RTOP. Comments made about the instrument were noted and used to improve on the classroom observation of teachers before and after the intervention activities. The RTOP is attached as Appendix D.

3.6.4 Reliability of the Reform Teaching Observation Protocol (RTOP)

The reform teaching observation protocol has been credited to be reliable by researchers who have used it before. Piburn et al., (2000) estimated that the correlation coefficient when RTOP was used in 32 independent observations was around 0.954. An arrangement was made to test the reliability of the RTOP by observing the class of other physics teachers in my school and one other school in the sample schools. Data collected from this pilot study were analysed quantitatively and the correlation coefficient determines the reliability of the instrument. The correlation coefficient *r* of the RTOP was 0.76 which indicated that there was a strong positive correlation based on the standards below.
If $r = 0$ no correlation, $0 < r \leq 0.3$ weak positive correlation, $0.3 < r \leq 0.7$ moderate positive correlation, $0.7 < r \leq 0.9$ strong positive correlation and $r = 1$ perfect positive correlation.

3.7 PILOT STUDY

A pilot study is a small-scale introductory study conducted to evaluate the feasibility and improve upon the study design prior to the performance of the main research. Johnson and Christensen (2008) explained that it is an introductory text of a research instrument. Research instruments are pilot-tested for the following reasons, as proffered by (McMillan & Schumacher, 2001, p. 185; Wilson & Sapsford, 2006):

1. To eliminate difficulties in wording and biased items;
2. To gain feedback on the appropriateness of the instrument;
3. To gain feedback on the appropriateness of the layout of the instrument;
4. To check the time it takes for the respondents to complete the questions; and
5. To check problems that has been experienced by respondents so that the necessary adjustments can be made.

Three (3) schools from the district that did not form part of the eight (8) for the study were selected for the pilot study. Six (6) teachers were purposively selected for testing the questionnaire. The questionnaire was administered to these high school physics teachers from the selected schools. The respondents were requested to comment on the time taken to complete the first questionnaire which attempts to establish teachers' initial knowledge on PBL. They were also requested to point out questions that were not clear or difficult to answer. The first questionnaire took an average of 15 minutes to complete. The second questionnaire, since it was based on the first one, only underwent content and face validity performed by experts.

To increase the validity of the instruments, the responses were analysed, which resulted in restructuring the questions with the help of my supervisor. For instance, some questions were changed from closed-ended to open-ended to enable the researcher to obtain in-depth information from respondents. Such questions as:

1. Do you know what problem-based learning (PBL) is?

Was changed to:
Provide a definition for problem-based learning (PBL) from your perspective.

2. Do you know what an ill-structured problem is?

Was changed to:
What do you think are the requirements for a problem when you use the problem-based learning (PBL) approach?

McMillan and Schumacher (2001) elaborated: qualitative researchers normally use a combination of data collection methods to enhance reliability in data collection. In addition to the questionnaire, an interview guide was also used to collect qualitative data from respondents, and therefore it was necessary to pilot-test the instrument. According to Cohen, Adelman and Thompson, (2000), pilot testing is crucial due to the benefits that come with it, which include: increased reliability, validity and practicability of the instrument. Participants were interviewed to test the suitability of the interview protocol. Each interview was taped and transcribed for clarity and to determine the average length of the interview. It took participants 20 minutes to respond to the interview questions.

Again, Physical Science lessons were observed for one hour both in grades 10 and 11 to check the suitability of the Reform Teaching Observation Protocol (RTOP). The instrument was found to be reliable as it was able to collect all data needed to assess the teachers' manner of delivery in the classroom.

3.8 DATA COLLECTION

Data collection is a systematic approach to gather information and variables that researchers are interested in, with a view to answer a research question (McMillan & Schumacher, 2001, p. 180). The characteristics of a case study research design involved using multiple sources and methods in the data collection process. Gay, Mills and Airasian, (2006, p. 446) recommended that researchers should not depend on one data collection method only. In educational research, several methods including the following are used: tests, interviews, questionnaires, observation, and focus groups (Johnson & Christensen, 2008, p. 162). A researcher using the case study research design determines what evidence to collect and what analysis technique to use with the data to answer the research question(s). Therefore, in this research, the researcher employed questionnaires, interviewing and a lesson observation schedule to collect data to answer the research questions.

Before data were collected on this study, a familiarization visit was made to the sampled schools in April 2018 with the letter from the Department of Education which

granted the researcher permission to conduct the study. The reason for this visit was to create a good working relationship with the schools and the physics teachers. The necessary arrangements were made with the schools and subsequently, letters of consent were issued to the principals, Physical Science teachers, and Physical Science learners to be handed over to their parents. Timetables were collected to know when to make an appointment for lesson observation. The researcher returned to the schools the following week for the actual study. During this visit, lessons were observed to determine the kind of teaching method teacher's use in their classrooms and the first questionnaire administered to collect data on teachers' initial knowledge of and skills applied during PBL. A four-weekend professional development workshop for teachers was organized from the 21st of April 2018 to the 19th of May 2018 to develop their skills and competencies in organizing PBL physics classes.

The second questionnaire was administered the last day of the workshop to collect data on teachers' experiences during the workshop and the level of acquisition of knowledge concerning PBL. The implementation of the PBL strategy took place immediately after the workshops, starting from the 21st of May 2018 to the 4th of June 2018. A follow-up visit was made to the schools from the 28th of May 2018 to the 4th of June 2018, which was during the implementation period to observe lessons and collect data on how the teachers were implementing the PBL strategy in their classrooms by the Reform Teaching Observation Protocol (RTOP). Again, during the same period, teachers were interviewed to collect data on their experiences during and after the implementation of the PBL strategy. The interviews also touched on collecting data on the successes and challenges of the strategy experienced by the teachers during the implementation process. An interview was conducted with each teacher immediately after the lesson observation. The collection of data for the study therefore ended on the 4th of June 2018.

3.9 DATA ANALYSIS

Gay et al.,(2006, p. 5) described data analysis as being a systematic organization and synthesis of data that comprises using one or more statistical techniques. Once all the data are secured, organized and quantified, it is time for the actual analysis to begin.

The data collected were analysed using a combination of descriptive statistics and thematic analysis.

The data in part 1 section A that presents biographical information of physics teachers in the sampled high schools were collected using the quantitative data analysis technique and represented statistically. McMillan and Schumacher (2010, p.149) explained, are tools that help assist a researcher in organising and interpreting numbers derived from measuring a trait or variable. Basically, statistics are used to organize and analyse quantitative data. They are broadly categorized into two types, namely descriptive statistics and inferential statistics (McMillan & Schumacher, 2010). The descriptive statistical analysis technique which transforms a set of numbers or observations into indices that define data was used to present an analysis of these data.

Furthermore, the thematic analysis technique was used to analyse the qualitative data collected in part 1 section B and part 2 of the questionnaire. Nevertheless, Braun and Clarke (2006, p. 79) defined thematic analysis as a method for identifying, analysing and reporting patterns within data. They further indicated that thematic analysis emphasizes examining analytically, investigating, and recording patterns or ‘themes’. Braun and Clarke (2006, pp. 3, 77-101) describe six steps for conducting thematic analysis:

1. Familiarizing yourself with your data
2. Generating initial codes
3. Searching for themes or patterns
4. Reviewing themes
5. Defining and naming themes
6. Producing the report

3.9.1 Analysis of questionnaires

The two questionnaires were analysed as follows:

Questionnaire One (1) Before Intervention (Q1BI)

Section A of Q1BI on teachers' biographical information was analysed quantitatively using frequency count. In the analysis each characteristic picked for instance age group, the number of teachers falling within each group were recorded in a frequency table. Furthermore, the numbers obtained in the frequency column were converted into percentages. Finally, the data in the tables were used to draw bar graphs. From each graph, the length of the bar represents the percentage of participants in a specific group. Subsequently, the process continued with all other biographical questions indicated in the questionnaire (section 4.2.1).

Questionnaire Q1BI section B and Q2AI

Q1BI section B and Q2AI were analysed qualitatively by presenting the analysis of physics teachers' experiences in PBL before and after the intervention workshop. During the analysis, three themes were identified (section 4.3).

1. Teachers' preferences for teaching strategy prior to intervention
2. Teachers' knowledge of PBL before intervention and after the intervention.
3. Teachers' reflection on PBL after the intervention.

A table for theme 1 was compiled with three columns to indicate the teachers' teaching strategy, reasons and frequency. The information collected from the table was later analysed and supported with evidence from literature (section 4.3.1).

Also, theme 2 consisted of six questions. However, in each of the six questions, data were collected in two tables representing the data collected before (Q1BI section B) and after intervention (Q2AI). Similarly, the data on theme 2 were collected using a three-column frequency table; description, teacher’s excerpt, frequency. The data collected were analysed simultaneously as before intervention and after the intervention. Furthermore, the information obtained was later interpreted and supported with evidence from literature (section 4.3.2).

Finally, the third theme has two questions from Q2AI and assesses teacher's reflection on PBL. Data were collected in the same manner as in the second theme with a three-column table and analysed in the same manner (section 4.3.3).

3.9.2 Analysis of the Reform Teaching Observation Protocol (RTOP)

The reform teaching observation protocol was analysed using five main constructs (section 4.4).

1. lesson plan and implementation
2. propositional content knowledge
3. procedural content knowledge
4. classroom culture (communicative interactions)
5. classroom culture (teacher/student or student/student interaction)

Furthermore, each of these constructs has five teaching criteria. Subsequently, each teacher's performance before and during the implementation of the PBL strategy was based on these practices. A scale of 0 – 4 was used to rate the teacher's performance as either no, low, moderate, high or very high depending on how much effort the teacher put in exhibiting the specific practices. However, the number of teachers that exhibit a specific practice was recorded in a table (sections 4.4.1 and 4.4.5). Subsequently, the numbers were later converted into percentages. Each of the practices under the five constructs was analysed simultaneously as before PBL and during the implementation of PBL to assess a change in the teacher's teaching practices. Finally, the results obtained were interpreted and supported with evidence from literature (sections 4.4.1 to 4.4.5).

3.9.3 Analysis of interview protocol

The responses from the semi-structured interview conducted with the physics teachers were coded and transcribed into themes. Three themes were identified:

1. Teachers' experiences before and after implementation of the PBL strategy

2. Teachers' successes during the implementation of the PBL strategy at schools
3. Teachers' challenges during the implementation of the PBL strategy at schools

Section 1 was transcribed and classified into 6 themes and section two into 12 themes. Furthermore, the responses of teachers under each theme were collected in a four-column frequency table; theme, description, teacher's excerpt, frequency. Again, the numbers under frequency column were converted into percentages. Finally, the results obtained were later interpreted and supported with evidence from literature (see section 4.5).

3.10 INTERVENTION

A document on how to apply the PBL strategy to teach current electricity was prepared and given to participants during the intervention workshop. The document was compiled from the literature review of this study. However, it focuses on:

1. The importance of professional development
2. The objectives of having professional development in this study
3. The definition of problem-based learning (PBL) and project-based learning
4. How to write a good driving question
5. The processes of project-based learning
6. The processes of problem-based learning
7. How to teach current electricity using the problem-based learning (PBL) approach

Day 1: A slide presentation was done to give the participant a clear view of what PBL entails (see Appendix J). This presentation focuses on the outline above ensuring that teachers are well-educated on the requirement of a problem, writing good driving questions or ill-structured problems and factors to consider, the teacher's role in a PBL class and the processes of PBL.

Random groups were formed with no interference from the researcher. The researcher only indicated that there had to be 4 groups and 4 members in each group. The 30-page hand-out was given to each member of each group. The groups discussed the processes of PBL and applied it in the next meeting's activity (see Appendix K).

Days 2 & 3: the PBL physics class: With the researcher as the facilitator, the groups transferred the knowledge onto the processes of PBL and engaged in a PBL lesson on current electricity. This activity took two days.

Day 4: the fourth meeting was to prepare for implementation, reflection and filling in the second questionnaire (Q2AI).

3.11 OVERVIEW OF RESEARCH METHODOLOGY AND INSTRUMENTS USED

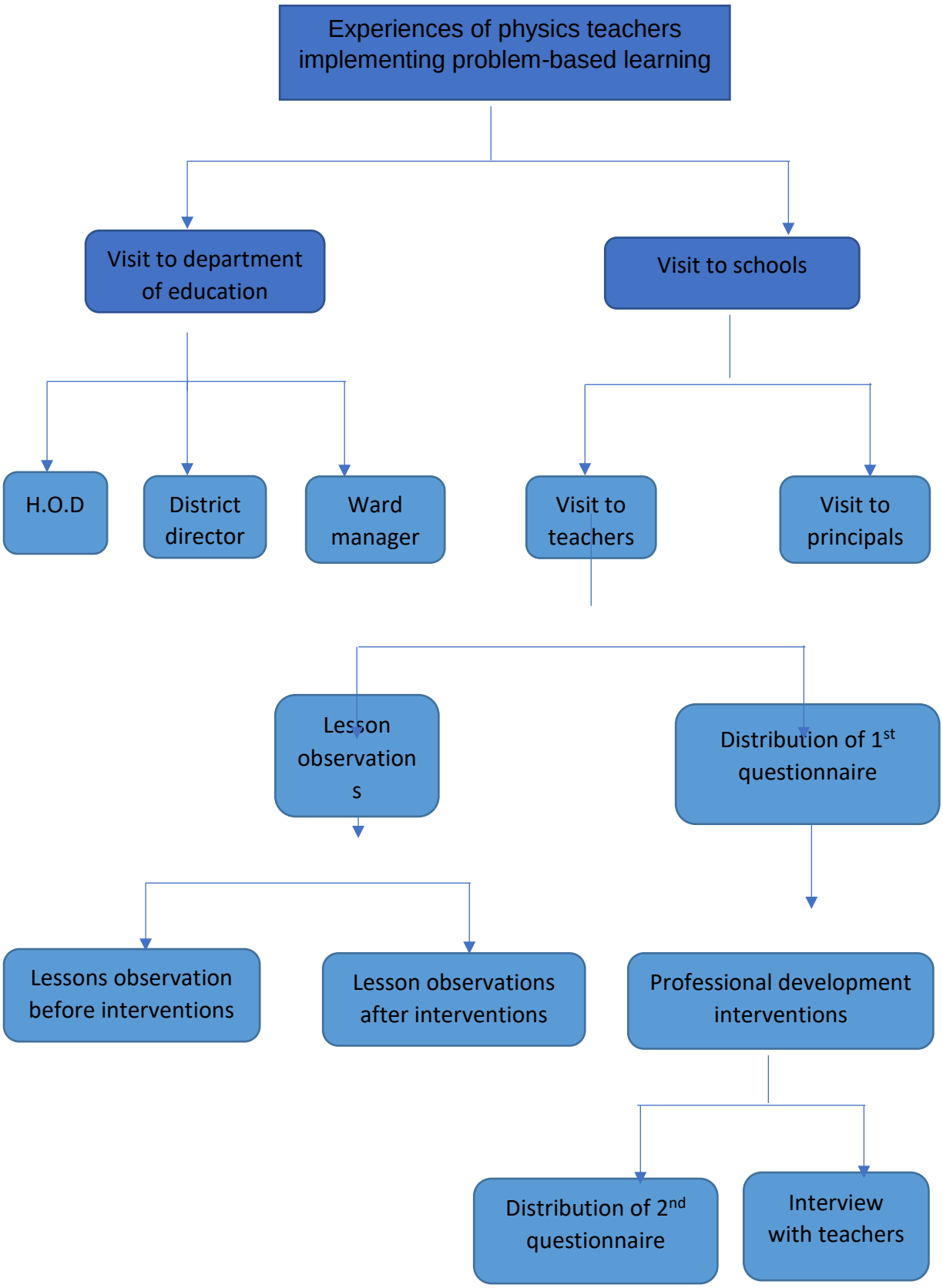


Figure 3.2: Research procedure

3.12 ETHICAL CONSIDERATIONS

McMillan and Schumacher (2001, p. 196) defined the term *ethics* as referring to a system of moral principles that people use to decide the rightness or the wrongness of certain actions and to the goodness or badness of the motives and ends of such actions. Researchers are therefore required to take into account the following ethical issues: informed consent, avoidance of harm, violation of privacy, anonymity and confidentiality, deceiving respondents and respect for human dignity of which encompasses right of full disclosure which reminds anyone who is involved in research to be aware of (Johnson & Christensen, 2008, pp. 101, 118-119). In this study, respondents were assured of anonymity and confidentiality. The purpose and the procedures of the study were explained to educators involved before questionnaires were administered.

3.12.1 Official Permission

Permission was requested from the KwaZulu-Natal Department of Education to conduct the research in eight selected high schools at the Entsikene cluster in the Harry Gwala district by writing a letter (Appendix G) requesting the education office to permit me to conduct the study. Permission to conduct research was granted by the Department of Education (Appendix H). A letter was also sent to the district director, the circuit manager, and the principals requesting permission to conduct this study. Responses from all the gatekeepers were positive.

The official permission from Evaluation Facilitation Group (EFG) of the Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT) to use the RTOP was attached as Appendix I.

3.12.2 Informed Consent Form

Informed consent forms were issued to all the respondents on which they indicated their willingness to participate by signing it. Johnson and Christensen (2008, p. 112) explained that informed consent is the procedure by means of which individuals decide to participate in a study or not after having been told what the study entails.

3.12.3 Rights of Participants

The respondents were made aware that their participation was voluntary and that they had the right to withdraw from the study at any time if they so wished.

3.12.4 Confidentiality

Confidentiality limits access or places restrictions on certain types of information. According to Cohen and Manion (1989, p. 24), it refers to agreements between people that limit others' access to private information. In other words, it indicates the handling of information in a confidential manner. The participants were assured of confidentiality; that the collection of data was for academic purposes only.

3.12.5 Anonymity

To ensure anonymity the respondents were told not to write their names and/or names of their schools on the questionnaires. However, in this study, respondents were identified with letters of the English alphabet so that the information on follow-up interviews could be put together with that of the two questionnaires for consistency during analysis. Cohen and Manion (1989) argue that it often is necessary to identify respondents, so that reminders could be sent to them to respond to the questions or respond to follow-up interviews. Information given anonymously ensured the privacy of the subjects.

3.13 SUMMARY OF THE CHAPTER

This chapter describes all the steps the research followed in other to carry out the study. The chapter gives detailed explanations of the research design, the sampling techniques, the various instruments for collecting data, validity and reliability of the instruments and how the instruments were constructed. The chapter also describes the sampling criteria, the population of the study and the study site. Again, the chapter gives a brief overview of the research methodology and instruments used for the research. Finally, the various ethical considerations that were followed before and during data collection which include official permission for conducting the study,

informed consent, right of participation, confidentiality and anonymity were also discussed. The next chapter will depend on the steps outlined in chapter three to collect data, represent the data and analyse the data; in other words to identify a meaningful pattern.

CHAPTER FOUR

DATA PRESENTATION, ANALYSIS, AND INTERPRETATIONS

4.1 INTRODUCTION

The data collected were to answer the following research questions.

Main question:

What are the experiences of physics teachers when implementing Problem-Based Learning (PBL)in their classrooms?

Sub-questions:

1. What are the physics teachers' experiences when implementing PBL, prior to an intervention?
2. How do Physical Science teachers implement PBL in their classrooms?
3. What are the successes and challenges of these teachers when implementing PBL in their classrooms?

To answer these research questions, three research instruments were applied, namely two questionnaires (Q1BI and Q2AI), interviews, and Reform Teaching Observation Protocol (RTOP). The first questionnaire was administered to the physics teachers prior to the intervention workshop presented to them by the researcher on the use of PBL. The second questionnaire was handed out to be answered by the teachers immediately after the intervention to assess their level of acquisition of knowledge on PBL. The teachers implemented the PBL strategy for 2 weeks during which lessons were observed, and thereafter interviews were conducted by the researcher with each teacher directly after the observation of each teacher’s lesson. The main aim of these interviews was to determine their experiences during the implementation of the PBL strategy and to assess the successes and challenges they faced during the implementation process.

4.2 RESULTS AND INTERPRETATIONS OF Q1BI SECTION A

The information presented in this section was the biographical information of the physics teachers teaching in high schools at the Entsikeni cluster, Harry Gwala district. The data collected from the respondents using Q1BI section A were presented and analysed quantitatively using the statistical instrument. The information obtained was converted into percentages and represented on bar graphs (see sections 4.2.1 to 4.2.6).

The biographical information that was represented and analysed covers the following aspects;

1. Teacher's gender
2. Teacher's age group
3. Teacher's teaching experience
4. Teacher's academic qualifications
5. Teacher's professional qualifications
6. Teacher's major subjects studied during training as a teacher

4.2.1 Gender of Respondents

This section presents and analyses the data collected on the gender of physics teachers in the sampled high schools. The data was statistically represented by means of a bar graph and interpreted and supported by the literature.

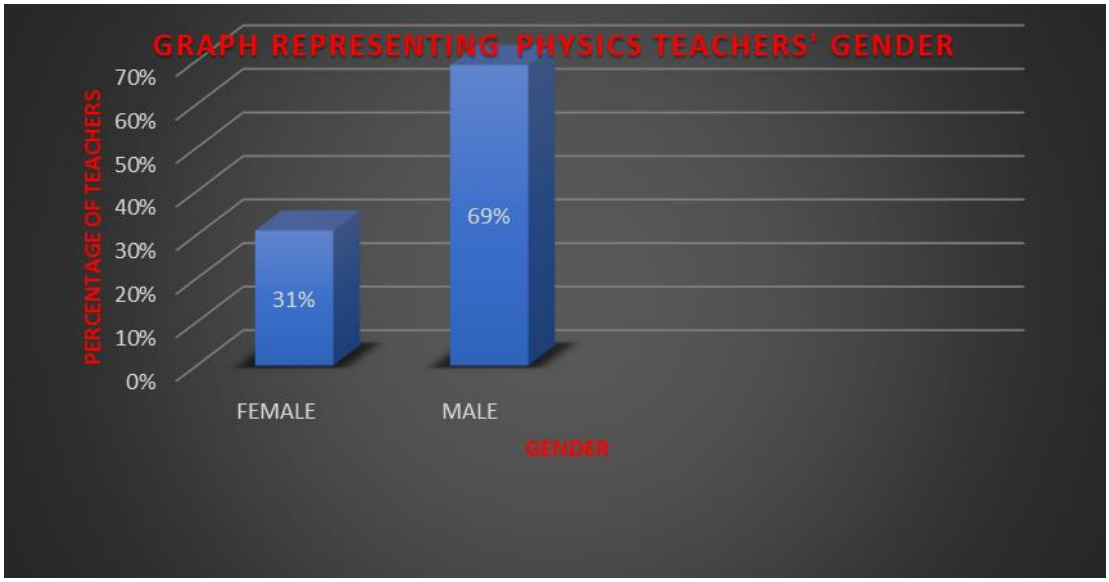


Figure 4.1: Gender of Physics Teachers

As can be seen in Figure 4.1, eleven (11)out of the sixteen (16) teachers were males and five (5) females. Male teachers dominate science teaching in many countries and South Africa is not an exception. Research has affirmed that males lead science-oriented professions (Lariviere, Gingras, Cronin & Sugimoto 2013; Eccles, & Wang, 2016) and this also is the case with teachers at Entsikeni cluster KwaZulu-Natal in South Africa. Lariviere et al.,(2013) and Eccles, & Wang (2016) supported the claim and indicated that even though more females are registered to offer science at lower levels in many countries, quite a small fraction end up at tertiary level and consequently less female science profession holders.

4.2.2 The age group of respondents

This section reports the analysis of the data collected on the age group of respondents and subsequently interpreted and supported by evidence from the literature. The graph in Figure 4.2 shows the representation of the data collected from the physics teachers on their age groups.

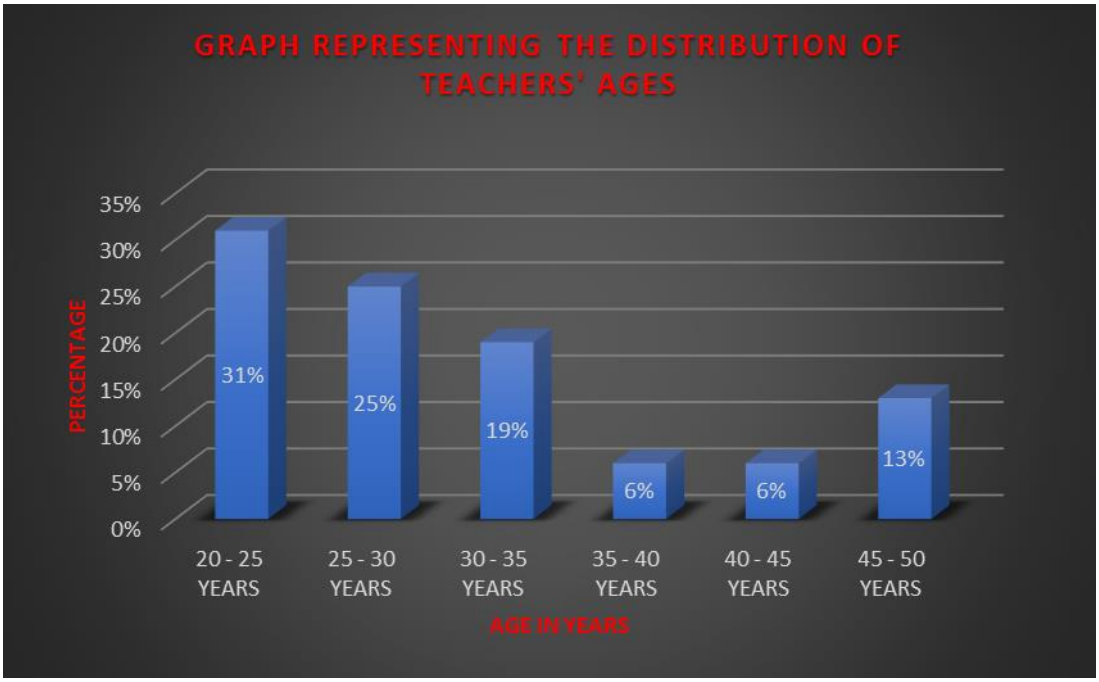


Figure 4.2: The age groups of respondents

The information from Figure 4.2 revealed that five (5)out of the sixteen (16) physics teachers were aged between 20 and 25 years, four (4) between ages 25 and 30 years and three (3) between ages 30 and 35 years. This leaves a total of twelve (12) of the teachers aged between 20 and 35 years, which means there are more active teachers teaching physics in the district's high schools but on the other hand could imply that they may be inexperienced in teaching physics since they have not taught for long.

Rice (2013) and Stronge (2018) adamantly states that experience promotes effectiveness; which means that more inexperience physics teachers in the district could indicate high ineffectiveness and subsequently could lead to poor performance of physics students in the district. Most teachers in the sample aged between 20 and 35 years could be new entrants. Research has affirmed that entering teachers in the teaching profession are less effective than those with some experience (Clotfelter, Ladd, Vigdor, 2007a; Stronge, 2018). This therefore could probably be one of the reasons for poor performance in Physical Science in the district.

4.2.3 Teaching experience of the respondents

The section presents the results of the distribution of teachers in terms of their experience in teaching physics in high schools.

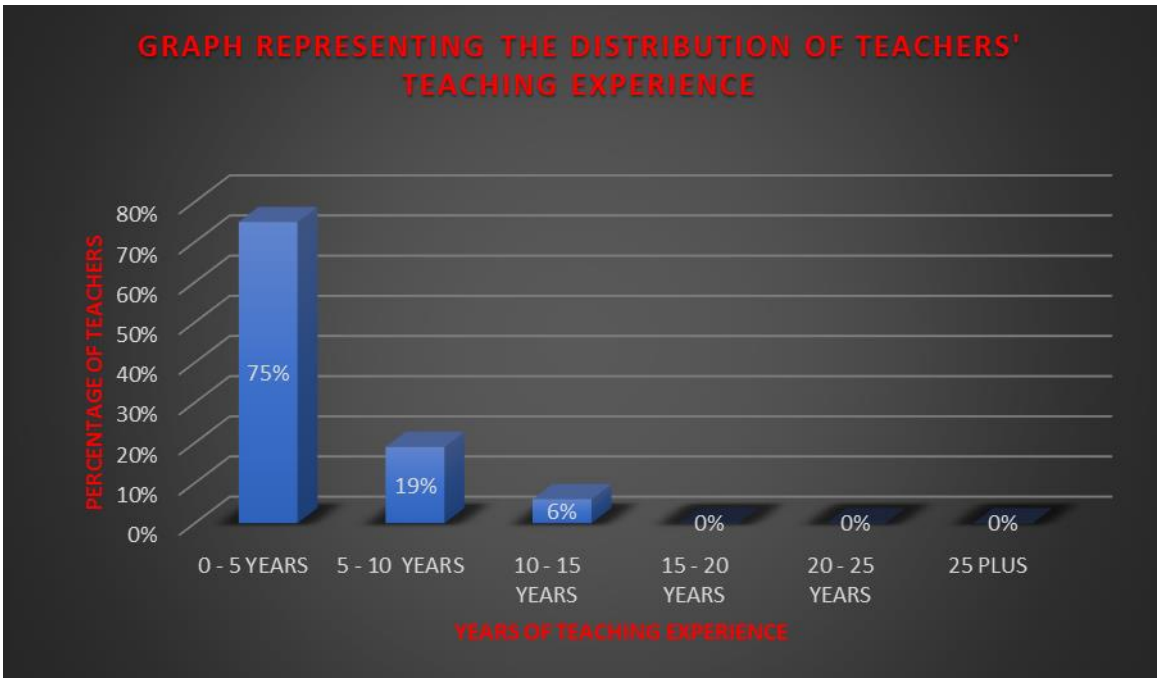


Figure 4.3: Teaching experiences of respondents

The information from Figure 4.3 shows that twelve (12) teachers in the sample have 0 – 5 years high school teaching experience. This implies that most of theteachers have less experienced in teaching physics in the FET, which could probably affect students' performance. Research has affirmed that teachers with more than 20 years of experience are more effective than teachers with no or little experience (Rice 2013; Stronge, 2018). When physics teachers are experienced, they are more likely to use inquiry and inquiry-based teaching which is ideal for science teaching (Tseng, Tuan & Chin 2013). However, studies have also revealed that if inexperienced trained teachers use an instructional method based on research, they tend to increase students' attendance, higher students' engagement and subsequently improve students' performance as compared to using the traditional instructional method (Deslauriers, Schelew, Wieman, 2011). Hence this justifies the need to introduce the PBL strategy to physics teachers in the district due to the large number of inexperienced physics teachers identified in the district teaching physics in the FET.

4.2.4 Academic Qualifications of Respondents

This section presents the results on the qualifications of physics teachers who participated in the study.

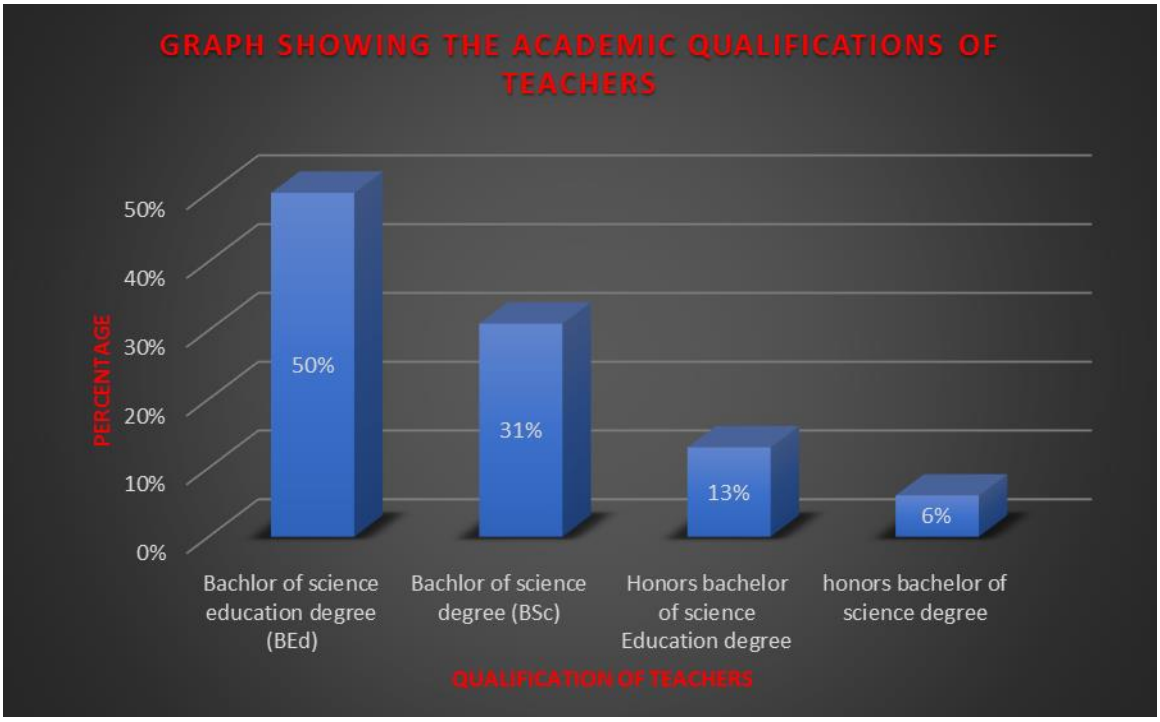


Figure 4.4: Academic qualifications of respondents

The information in Figure 4.4 indicates that teachers teaching physics at the Entsikeni cluster have a strong academic background, even though none of them have a master's or doctoral degree. The analysis shows that all the sample teachers have university degree in science with a strong conviction that they have knowledge in the subject matter. Zuzovsky (2009), Rice (2013) and (Stronge, 2018) indicated that teachers who have attained advanced degrees have a positive influence on learners' achievement in physics compared to those with lower degrees. It is therefore expected that learner performance in Physical Science could be very high in the district.

4.2.5 Respondents' professional qualifications

The section reports the results of respondents' professional qualifications.

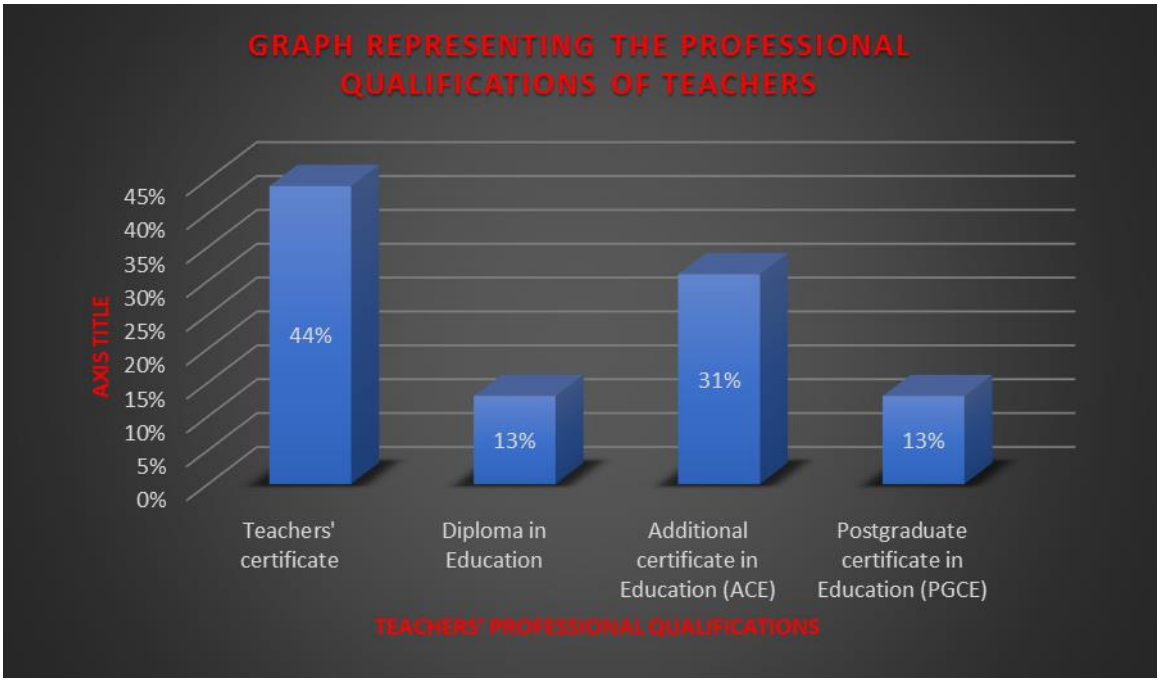


Figure 4.5: Respondents' professional qualifications

The data collected from Figure 4.5 indicated that all the sample teachers teaching Physical Science at the Entsikeni cluster were professionally qualified. Even though few teachers have a postgraduate certificate, many of them have a Bachelor of Education degree or the teachers' certificate (see Figure 4.5). The information collected indicates that seven (7)out of the sixteen (16) teachers are trained teachers with teachers' certificates. Furthermore, the analysis shows that five (5) out of the sixteen (16) have an Additional Certificate in Education, which probably means that they graduated with Bachelor of Science degrees and then studied education to make them professionally qualified.

As depicted in the graph in Figure 4.5 all the teachers are professionally qualified to teach science in high schools. Research affirmed that teacher qualifications such as certificate status, degree level, preparation, and experience predict students' achievement and increase productivity in secondary schools (Croninger, Rice, Rathbun, &Nishio, 2007; Stronge, 2018). This therefore means that much is expected from physics teachers in terms of student pass rate in the Harry Gwala district. This was consistent with the views of other researchers who claimed that professionally qualified teachers are likely to be effective in instructional strategies, students'

assessment, class management and personal qualities than are unqualified teachers (Stronge, Ward, Tucker &Hindman, 2007; Stronge, 2018).

4.2.6 Respondents' subject specialization

This section presents the results on subject specialization by teachers teaching Physical Science at Entsikeni cluster during their training to become teachers.

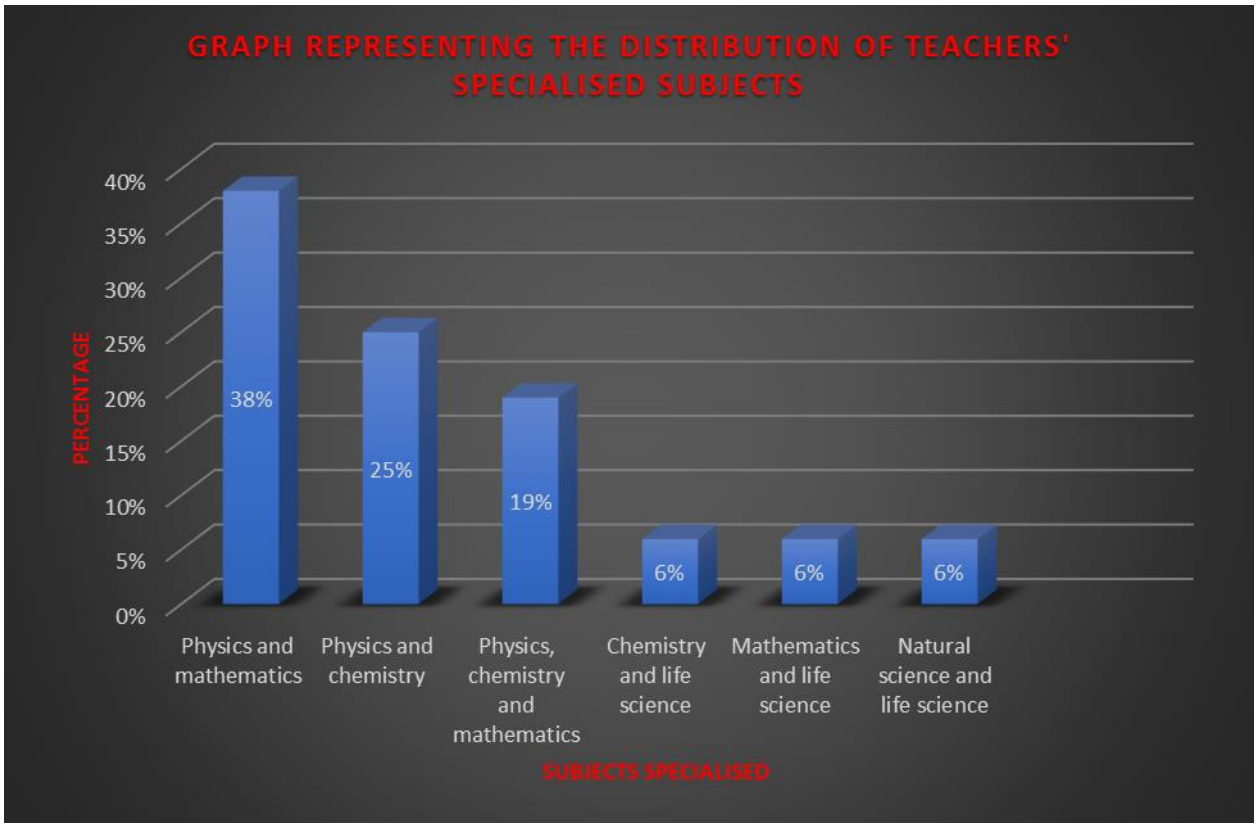


Figure 4.6: Respondents' subject specializations

The analysis from the graph in Figure 4.6 indicates that thirteen (13)out of the sixteen (16) teachers have the content base of the subject and a stronger background with the capability of teaching physics in high school. Research has shown that student achievement in physics is influenced much stronger by the teacher's qualification (Darling-Hammond &Youngs, 2002 p. 13; Stronge, 2018) and a strong content base (Kriek& Grayson, 2009). However, the analysis of the results shows that three (3) of the respondents are teaching Physical Science in high schools using their experience and knowledge they had from high school. In view of this, students' performance in

Physical Science in such schools probably could be very low. Even though from the previous analysis these teachers were noted to have education and as such are professionally qualified to teach in high school but lack the content base to teach physics. This may probably also account for the poor performance in Physical Science in the district.

4.3 RESULTS AND INTERPRETATIONS OF Q1BI SECTION B, AND Q2AI

This section presents the results of the analysis of physics teachers' experience in PBL before and after having attended the intervention workshop. The section consists of three themes;

1. Teachers' preferences concerning teaching strategy prior to intervention
2. Teachers' knowledge of PBL before intervention and after the intervention.
3. Teachers' reflection on PBL after the intervention.

4.3.1 Teachers' preferences concerning teaching strategy prior to intervention

When teachers' were asked, 'what teaching strategy do you prefer to teach you physic students', they wrote various teaching strategies. The responses from the teachers were represented and analysed. The results from the analysis were further interpreted and supported by evidence from the literature. Table 4.1 below indicates the teachers' preferences of teaching strategy, the reasons for their choice and the number of teachers that prefer each teaching strategy.

Table 4.1: Teachers' preference of teaching strategy and reason

Preferred strategies prior to intervention	Reasons	Frequency (N= 16)
Problem solving	A1: 'increases learners' participation and involvement' H1: 'involve learners to do more' E2: 'it ensures learner participation'	3
Demonstration	A2: 'it develops ability to answer the question 'how' E1:'it provides opportunity to follow procedures' C1: 'it is the easiest for students to understand the content'	3
Group discussion	G2: 'It gets learners involved in the learning' D2: 'help learners come up with their own ideas'.	2
Question and answer	B1: 'to check where the difficulty is' C2; 'I think interaction with learners is the best way of teaching, the questions and answer method because is where you interact with learners and see those who understand easily'	2
Inquiry	D1: 'to check where they have problem and go through that section once again'	1
Lecture	F2: 'It helps to cover the syllabus easily'	2
No response		3

Problem-solving method

As gathered from Table 4.1, three (3) out of the sixteen (16) teachers prefer the problem-solving method for various reasons. Problem-solving, as the teachers mentioned, is one of the products of applying the PBL strategy and affirmed by Surif, Ibrahimb and Mokhtarc (2013). The researchers indicated that problem-based learning (PBL) is a form of learning that results from the process of working towards the solution of a problem. This means that by applying the PBL strategy, the objective is problem-solving. The remarks of teacher A1 are indicated below.

A1: 'Problem-solving, because it increases learner participation and involvement in the teaching and learning process'

The significance of these teachers' preference to the problem-solving method is that they may probably be able to adjust easily to the PBL strategy which is the focus of this study.

Demonstration method

Three (3) other teachers out of the sixteen (16) indicated that they prefer the demonstration method. Various reasons were provided (Table 4.1) but the most popular one was: 'it develops in students the ability to answer the question 'how' because mathematics and science are all about doing and following procedures'. Lujan and DiCarlo (2006) support the idea that a demonstration method is a preferred strategy to teach mathematics and science, especially in small class sizes. This confirmed the claim by the teachers on their reason for their preferred strategy. As per teacher A2;

A2: 'Demonstration method, because when using the demonstration method, this method provides an opportunity for learners to follow the procedure, steps, and it also answers the question 'how' because maths and science is all about doing and following procedure'

Group discussion method

In another development, two teachers out of the sixteen (16) teachers indicated they prefer the group discussion method (Table 4.1). They stated the reason that 'students' can come out with their own responses and present them in the class'. The claim was consistent with the views of Wolff, Wagner, Poznanski, Schiller and Santen (2015) when they stated that the discussion method helps students develop problem-solving skills as they try out their own ideas on other students and the teacher. What makes the reason for the teachers' preference and the researchers claim similar to the PBL strategy are 'trying out own ideas, presenting ideas in class and developing problem-solving skills'

Furthermore, Barrett (2010) described discussion as characterized by long-standing give and take, which turns to improve students' critical thinking and problem-solving skills. Barrett (2010) supported Wolff, Wagner, Poznanski, Schiller and Santen (2015), by indicating that the discussion method is similar to the PBL strategy since it develops students' critical thinking and problem-solving skills. The teachers' preference probably could easily make them adapt to the PBL strategy since PBL includes discussion. Teacher D2 narrated;

> *D2: 'I prefer group discussion method because I want to let them come up with their own ideas among their groups and present as in class'.*

Question-and-answer method

Again, two teachers from the sample space indicated that they prefer to use the question-and-answer method. They stated the reason that 'it helps teachers to interact with students and is the best way to teach them' (Table 4.1). This claim is consistent with the views of Harvey and Light (2015) when they stated that questioning is an important interaction that influences students' learning. The teachers prefer this strategy. It is like the PBL because the question-and-answer approach is also applied in PBL lessons to keep students' investigation going in a positive direction (Gilkison, 2003). The narration of teacher C2 is indicated below;

> *C2; 'I think interaction with learners is the best way of teaching, the questions and answer method because is where you interact with learners and see those who understand easily'*

The advantage of these teachers' preference is that they may probably be able to adapt easily to the PBL strategy since PBL includes effective questioning.

Inquiry method

In addition, one teacher in the sample indicated the preference of using the inquiry method. The reason given does not actually support his preference. The reason was that 'it helps teachers to identify difficult sections and re-teach the section once again' (Table 4.1). Researchers describe inquiry-based learning as a strategy which starts

with a question and ends with students' discovery as evidence that learning has taken place (Kampa et al., 2016) and does not support teacher D1's reason. The teacher's remark is shown below;

> *D1: 'I prefer an inquiry method because in that way you are able to see if they have a problem in a particular section and go through that section once again'*

Research has indicated that inquiry-based learning is like PBL (section 2.3.3.2). The teachers' preference could probably make them easily form knowledge on the concept *PBL* since inquiry-based learning has been identified to include PBL (Krajcik, McNeill, &Reiser, 2008).

Lecture method

Finally, two other teachers out of the sixteen (16) teachers also prefer the lecture method with the reason that 'it helps to cover the annual teaching plan easily' (Table 4.1). This claim was consistent with the views of Çetin and Özdemi (2018), who stated that a large amount of topic can be covered in a single class period when using the lecture method. Teacher F2 narrated;

> *F2: 'I like the lecture method since it helps to cover the syllabus easily'*

Çetin and Özdemi (2018) see the strategy to have an added advantage of helping to develop students' language formation and listening skills as the process is characterized by long talks of the teacher. Barrows and Tamblyn (1980) supported Çetin and Özdemi (2018) when they noted that one of the main objectives of PBL is to enhance students' communication skills. This indicates that the lecture and the PBL strategy have a similar objective of developing students' communication skills (section 2.3.1.1). This perhaps means these teachers could probably prefer to combine their approach with the problem-based learning (PBL) strategy as their preferred strategy could be very useful in PBL as a roundup strategy.

The conclusion of the analysis of teachers' teaching preferences

In conclusion, from Table 4.1 and the analysis above, it is evidence that eleven (11) out of the sixteen (16) respondentsprefer a teaching strategy which aligns with the PBL strategy. Hence this suggests that these teachers could easily adapt to the PBL strategy. However, three (3) out of the sixteen (16) teachers did not answer the question and suggests that their teaching strategy probably does not align with the PBL strategy.

4.3.2 Teachers' knowledge of PBL prior to intervention and after the intervention

Result of the teachers' knowledge and skills in PBL before and after the intervention.

Six (6) main questions were analysed from the open-ended Q1BI section B which gave information on teachers' initial knowledge of and skills in PBL prior to application of the knowledge gained from the intervention workshop. Again, a further six (6) questions were analysed from open-ended Q2AI side by side with the first six questions from Q1BI section B to obtained information on the change in teachers' knowledge and skills in PBL immediately after the intervention. The significance of this is to establish whether teachers had gained enough knowledge and skills to implement the PBL strategy in their classrooms. The results obtained from these analyses were interpreted and supported by the literature.

Question 1: Provide a definition for problem-based learning (PBL)from your perspective.

Before intervention

Table 4.2: Teachers' responses to the definition of problem-based learning, before the intervention

Definition of PBL	Excerpt of teacher	Frequency N = 16
Active involvement	A1: 'problem-based learning is a type of teaching and learning where learners are engaged actively'	1
Problem-solving	B2: 'Problem-based learning is that which require learners to think at a particular level in order to provide a solution to a particular problem'	2
Real-world problem	G1: 'It is given learners scenarios, cases that have daily life situations and problem and they must apply their content knowledge in solving the problem'	1
No response		8
No relevance	B1: 'Problem-based learning, I think it is the problem that a particular learner face when he or she is learning'	4

Active involvement

Researchers are of the view that the focus of problem-based learning (PBL) is the active involvement of students (Tan, 2003), and that it shifts students from being passive observers to active participants in solving a given problem (Goodman, 2010). Teacher A1's definition supports this claim (Table 4.2). Constructivists also support problem-based learning (PBL) as learning by means of which 'learners are engaged actively' (teacher A1) by indicating that 'knowledge is not transmitted directly from one knower to another but is actively built up by the learner' (Driver et al., 1994, p.5).

Problem-solving

Teacher B2 described problem-based learning (PBL) to be a type of learning that requires students to think at a level to enable the student to solve a problem (Table 4.2). Tan (2003) supported this when he stated that problem-based learning (PBL) is designed to focus on students to think about solving the problem presented to them.

Real-world problem

A daily life problem where students apply their content knowledge to solve a problem is consistent with the views of Karaçalli and Korur (2014). These researchers indicated the need to include a project in a real-life situation when solving problems. This claim supports teacher G1's explanation of problem-based learning (PBL) as giving learners scenarios or cases that reflect daily life situations and a problem for learners to apply their content knowledge in solving the problem (Table 4.2).

The conclusion of the analysis of teachers' understanding of the concept* problem-based learning*, prior to intervention

In conclusion, from the analysis above, four (4) out of sixteen (16) teachers made submissions that have no meaning to the definition of problem-based learning. On the other hand eight (8) teachers from the respondents did not answer the question. This suggests twelve (12)out of the sixteen (16) respondents could not define problem-based learning (PBL) appropriately before the intervention. Subsequently, only four (4) out of the sixteen (16)teachers demonstrated some knowledge of the definition of problem-based learning. Teachers therefore need an intervention on PBL if they are to apply it in their classrooms.

After intervention

Table 4.3: Teachers' responses to the definition of problem-based learning after intervention

Definition of PBL	Excerpt of teacher	Frequency N = 16
Active involvement	A1: ' problem-based learning is a type of teaching and learning where an ill-structure problem is presented to learners and learners are engaged actively in research to solve it'	2
Problem-solving	H2:'It is a process where learners are equipped with skills that they can use to solve a problem. The	5

	learners are encouraged to work in groups and learn what they need to know to solve a problem'	
Real-world problem	G1: 'a type of teaching and learning whereby learners in small groups are posed with ill-structured problem in real-life situation, so that they apply their content knowledge to research and solve the problem.	4
Collaborative	F2: 'Problem-based learning is a learner-centred approach focusing on experiential learning with students learning in small collaborative in order to solve a problem'.	4
No response		1

Active involvement

From the evidence that was gathered and before intervention, one teacher defined the concept *problem-based learning(PBL)*as that it focuses on 'active involvement of learners'. However, after the intervention, two teachers defined the concept *focus on 'active involvement*' but improved on their definition describing their problem as 'ill-structured' and their activity as 'research' (Table 4.3). The definitions of these teachers focusing on 'active involvement' are consistent with the views of Tan (2003) and Goodman (2010). Similarly, the teachers describing their problem as 'ill-structured' is also supported Barrows (1996) who stated that in problem-based learning (PBL) ill-structured problems are presented as unresolved so that students will generate not simply multiple thoughts about the cause of the problem, but multiple thoughts on how to solve it. Teacher A1's definition of problem-based learning (PBL) as 'active involvement' in resolving an 'ill-structured problem' through 'research' is represented in Table 4.3

Problem-solving

In another development, two (2) teachers prior to interventions defined the concept to include problem-solving. Similarly, after the intervention five (5) teachers defined the concept as *'problem-solving*' but also extended their definition to include 'working in small groups' (Table 4.3). Hmelo-Silver (2004) supported this definition by indicating that problem-based learning (PBL) strategy is characterized by working in small

groups on a presented problem or case to resolve it. Teacher H2's explanation of the concept, which is consistent with the views of Hmelo-Silver (2004), is represented in Table 4.3 above.

Real-world problem

Furthermore, only one teacher, prior to intervention, explained PBL to include real-life problem. However, after the intervention, four teachers explained that is a type of learning which is based on the real-life problem (Table 4.3). The definition is consistent with the views of Dmitrenko (2017), who defined the concept as focusing on empirical learning organized around searching and problem-solving where students are encouraged to solve real-life structured problems. Teacher G1's explanation of problem-based learning (PBL) as consistent with the views of Dmitrenko (2017) is represented in Table 4.3 above.

Collaboration

In addition, four other teachers defined the concept including collaboration among learners (Table 4.3). Dolmans, De Grave, Wolfhagen and Van Der Vleuten (2005) and Dmitrenko (2017) supported these definitions when they define problem-based learning (PBL) as being a student-centred learning strategy that optimizes collaboration, contextualization, constructivism and self-directed learning. Teacher F2's explanation which describes the concept as learner-centred, experiential and collaborative learning, is represented in Table 4.3. However, no teacher prior to intervention defined PBL to include collaborations.

The conclusion of the analysis of teachers' understanding of the concept* problem-based learning*, after intervention

From the analysis, it can be concluded, after the intervention, that teachers had gained enough knowledge in PBL. Fifteen (15) out of the sixteen (16) sampled teachers demonstrated a good understanding of the concept *problem-based learning*. In contrast, only four teachers showed some knowledge of the concept, prior to the intervention.

Question 2: Describe the processes of problem-based learning (PBL)from your perspective

Before intervention

Table 4.4: Teachers' responses to the processes of problem-based learning, before intervention

Description	Excerpt of teacher	Frequency N = 16
Relevant to processes of PBL	G1: 'identifying the problem Define the identify problem Seek and brainstorm possible solutions Allocate resources that will assist in solutions Choose one solution and implement it Monitor the implementation Evaluate if the problem has been solved Re look and apply the process again if intended solution is not reached'	1
Not relevant to processes of PBL	G2: 'Process include observation, asking questions, categorizing, synthesizing, contrasting and comparing, taking conclusions and inferences'	7
No response		8

Relevant to the processes of PBL

As depicted in Table 4.4, only one teacher's response was relevant to the processes of problem-based learning. This claim was consistent with the views of Savery (2015) who stated that practically, in problem-based learning (PBL) classrooms, students are first presented with a problem at the start of a lesson, they discuss the problem in small groups, define what the problem is, brainstorm the problem to identify a learning issue, reason through the problem and indicate plans to resolve the problem.

Not relevant to the processes of PBL

Unfortunately, seven (7) other teachers responded to the question but their responses were not relevant to the processes of problem-based learning (PBL) (Table 4.4).

The conclusion of the analysis of teachers' understanding of the processes of problem-based learning, prior to intervention

In conclusion, eight (8) out of the sixteen (16) teachers did not respond to the question (Table 4.4). Similarly, seven (7) of them responded incorrectly. As a result, fifteen (15)out of the sixteen (16) respondents probably have no knowledge of the processes of problem-based learning. However, only one (1) of the respondents demonstrated some knowledge of the processes of problem-based learning. Therefore, the teachers' knowledge of the processes of problem-based learning (PBL) needs to be enriched through intervention if they are to apply in their classrooms.

After intervention

Table 4.5: Teachers' responses to processes of problem-based learning, after intervention

Description	Excerpt of teacher	Frequency N = 16
Relevance to the processes of PBL	H2: 'The process of a problem-based learning requires the learners to first explore the issues and state what it is its nature. The learners then define the issue in a way that makes it a problem in their lives and how it affects them in their lives. Find more information about the issue by doing research; that is looking at how the problem also affects other people or our environment. The learners now look at all the knowledge they have gained and formulate a solution to the issue. They can also involve other people who are affected and their opinion. Lastly, the learners present their solutions and review their presentation'	14
Not relevant to the processes of PBL		0
No response		2

Relevant to the processes of PBL

Evidence from the previous analysis shows that only one teacher responded to this question correctly, before interventions (Table 4.4). However, after the intervention,

fourteen (14) teachers responded to the question and their responses were relevant to the processes of problem-based learning (PBL) (Table 4.5). These responses were consistent with the views of the claim made by Savery (2015) on the processes of problem-based learning (PBL) in the previous presentation in the section, before the intervention. The response of teacher H2 is represented in Table 4.5 above.

Two teachers did not respond to the question.

The conclusion of the analysis of teacher understands of the processes of problem-based learning, before intervention

It could be concluded from the analysis, performed after the intervention, that fourteen (14) out of the sixteen (16) teachers had gained knowledge of the processes of PBL. However, two (2) of them did not respond to the question, which probably means that they still do not have knowledge of the processes of PBL. This shows that most of the teachers are ready to implement the strategy in their physics classrooms.

Question 3: What do you think are the requirements for a problem when you use the problem-based learning (PBL) approach?

Before intervention

Table 4.6: Teachers' responses to the requirement of a problem when using the problem-based learning (PBL)strategy, before intervention

Description	Excerpt of teacher	Frequency N = 16
Relevant to the requirements of a problem		0
Not relevant to the requirement of a problem	C1: 'I think that the requirements for a problem when you use problem-based learning is to first understand the content before presenting it to learners then find approach use some reserves, so	6
No response		10

Relevant to the requirements of a problem

Researchers are of the view that the requirement of a problem when using a problem-based learning (PBL) strategy must have the following characteristics: it must be based on real-life situations, should be open-ended, must take into account the content object of the topic, should be interesting to students, the needs of students and their future careers must be considered, must involve all members of the group, and finally, must engage students to make decisions or judgements based on information gained during the research. No teacher responded to this question correctly, prior to the intervention (Table 4.6).

Not relevant to the requirements of a problem

Unfortunately, six (6) out of the sixteen (16) teachers responded to the question, but their responses were not relevant to the requirements of a problem when applying the problem-based learning (PBL) strategy (Table 4.6). The response of teacher C2 is represented in Table 4.6 above. The claim by Barrett (2001) on the requirement of a problem indicates that the response of teacher C1 is not relevant to the requirement of a problem.

However, ten (10) out of the sixteen (16) teachers did not respond to the question.

The conclusion of the analysis of teachers' understanding of the requirement of a problem, prior to intervention

In conclusion, none of the respondents have knowledge of the requirement of a problem when applying the problem-based learning (PBL) strategy. As a result, teachers need an intervention if they must experience and implement PBL in their classrooms.

After intervention

Table 4.7: Teachers' responses to the requirement of a problem when using the problem-based learning (PBL) strategy, after intervention

Description	Excerpt of teacher	Frequency N = 16
Relevant to the requirements of problem	H2: 'Firstly the problem should be at the level of the learners' knowledge, and it must stimulate their interests; in other words, it must be a problem that will make them want to know more and ways to solve it. All learners in a group must be assigned with duties so that they can all feel needed in their group and will emphasize responsibility. The learners should value the importance of working together as a team and understand that they are not competing with each other. The problem must be based on real-life problems/situation so that the learners can relate; it should be open-ended. The content objectives of the topic should be incorporated into the problems. The problem should require critical research from different sources and this should allow learners to make decisions from a different source and this should allow learners to make decisions based on the facts and information that is true; not their personal opinions'.	14

Not relevant to the requirement of problem	B2: ‘1. The problem should relate to learners’ previous knowledge 2. provide challenging title for the problem to engage students’ interest 3. the problem should be well-defined’	1
No response		1

Relevant to the requirements of a problem

From the result of the analysis, fourteen (14) out of the sixteen (16) teachers' responses were relevant to the requirement of a problem after the intervention (Table 4.7). Their claim was consistent with the views of Barrett (2001) as per his narration in the section before intervention in this question 3. The claim of teacher H2 is indicated in Table 4.7 above.

Not relevant to the requirements of a problem

However, one teacher's response was found to be irrelevant to the requirement of a problem (4.7). The claims by Barrett (2001) indicate that teacher B2's response in Table 4.7 is not relevant to the requirements of a problem.

Similarly, one teacher did not respond to the question.

The conclusion of the analysis of teachers understanding of the requirement of a problem, after intervention

In conclusion, two (2) out of the sixteen (16) respondents have no knowledge of how to structure a problem. However, fourteen (14) of them demonstrated some knowledge of the requirement of structuring a problem. As a result, teachers, after the intervention, had gained knowledge of how to structure a problem.

Question 4

Describe how you will present the following content in your physics class

Grade: 10

Topic: the impact of electrical energy on the over-growing industry

Content: current electricity

Before intervention

Table 4.8: Teachers' skills in developing a lesson on current electricity prior to intervention

Description	Excerpt of teacher	Frequency N = 16
Student's Relevant Previous Knowledge (RPK) and learner-centred strategy		0
Student's RPK and teacher-centred strategy	H2: 'Reviewing with learners on their relevant prior knowledge on electricity. Brainstorm with the learners what electricity or electrical energy is. Stating ohms law of electricity and providing the formula for the ohms law. Given various definitions or terminologies of the formula. Solve questions under electricity with the learners'	7
No students RPK and learner-centred strategy	D2: 'practical- using apparatus like rheostat, voltmeter, ammeter, resistors, cells, conducting wires connect parallel as well as series connection'	1
No students RPK and teacher-centred strategy	A1: 'Define energy. Define electrical energy. Define current. Differentiate all different types of currents. Explain the relationship between variables. Use the diagram to explain. Relate the impact of electrical energy in our daily practices'	6
no response		2

Lesson introduced with Student's Relevant Previous Knowledge (RPK) and learner-centred strategy

Unfortunately, from the information gathered in Table 4.8 above, none of the sample teachers prepared a lesson that was learner-centred and considered students' relevant previous knowledge. In a similar vein, two (2) teachers did not respond to the question.

Lesson introduced with Student's RPK and teacher-centred strategy

Seven teachers (7) prepared lessons that considered students' relevant previous knowledge (Table 4.8). However, the lessons presented were teacher-centred. Basically, teachers used the traditional instructional strategy and researchers are of the view that lectures do not assist students in developing conceptual understanding of the physics concept when using this approach (Michael, 2006; Karaçalli&Korur, 2014; Çetin, &Özdemir, 2018).This is because information is made readily available, and student need not search for them, and teaching and learning are devoid of practical or real-life situations (Orlich et al., 2012).

Lesson introduced without students' RPK and learner-centred strategy

From the analysis it became clear that one teacher prepared a lesson which did not consider students' relevance to previous knowledge, but it was learner-centred (Table 4.8). The response of teacher D2 is represented in Table 4.8 above. Various researchers have affirmed the importance of students' relevant previous knowledge in the teaching and learning of mathematics and science (Niess, 2005; Beard 2013, Driver et al., 2014). Constructivists believes that prior knowledge impacts on the learning process (Driver et al., 2014; Gautam, 2018) and warned that information not connected to students' prior knowledge would quickly be forgotten. Hence, connect with the Vygotsky's zone of proximal development (Vygotsky, 1978).

Lesson introduced without students' RPK and teacher-centred strategy

Six (6) other teachers presented a lesson which did not consider students' relevant previous knowledge. However, the lessons were teacher-centred (Table 4.8). An excerpt of teacher A1 is represented in Table 4.8. As discussed in section 2.2.1 and earlier in this section, the teacher-centred strategy does not help in understanding physics concepts (Michael, 2006; Karaçalli&Korur, 2014; Çetin, &Özdemir, 2018).

The conclusion of the analysis of teachers' lesson presentation before intervention

In conclusion, seven (7) out of the sixteen (16) teachers presented lessons without considering students' RPK. In addition, thirteen (13) out of the sixteen (16) teachers prepared lessons that were teacher-centred. Only one (1) out of the sixteen (16) teacher presented a lesson that was learner-centred but then did not consider students' RPK. As a result, teachers need to be presented with an intervention to possibly improve their lesson delivery.

After intervention

Table 4.9: Teachers' skills in developing a lesson on current electricity, after intervention

Description	Excerpt of teacher	Frequency N = 16
Student's RPK and learner-centred strategy	B1**: 'Introduction;** - formulating the ill-structured problem that has a real-life implication, - formation of groups; put learners into groups of 4 and review their previous knowledge by question and answers **Development;** I find out what they know about electricity. Present the problem to them and guide them to do the following - making the problem clear. Each group is given the problem and tries to understand it - A brainstorming section, here groups are advised to produce questions relating to the problem - Each group must find out how much its individual members already know about the questions from the previous steps	14

	- the groups make are asked to make a schematic sketch of the problem where causes and effects and possible solutions to the problem are drawn - group members followed the lessons aim and distribute work among themselves - group members engage in research to address the problem - The groups are given the chance to discuss their findings with other group members. During this collaboration the groups try to ask and answer the following questions; Do we have enough necessary information to solve the problem? A positive answer lead to the report writing stage while a negative answer will call for the groups to do additional research' – the groups are made to write a report of their findings and present to the class – individual and group assessment is done to ensure learners have learned new things'	
Student's RPK and teacher-centred strategy	D1: - ask them few questions on what they already know -Introduce topic explaining the concepts electrical energy, -explain series and parallel connections -explain Ohm's law - do some calculations on current, resistance and voltage - do calculations on power, electrical energy and how power is sold. - discuss with learners the economic importance of electricity in household and industries - give them work to test their understanding	2

The lesson introduces Student's RPK and learner-centred strategy

After the intervention, fourteen (14) out of the sixteen (16) teachers presented lessons which were learner-centred and considered students' relevant previous knowledge (Table 4.9). The excerpts of teacher B1 are represented in Table 4.9.

The lesson introduces Students' RPK and teacher-centred strategy

However, two (2) out of the sixteen (16) teachers prepared lessons that considered students' RPK but applied the teacher-centred approach (Table 4.9). As indicated earlier in the section before intervention in question 4, the teacher-centred strategy does not help the study of physics (Michael, 2006; Karaçalli & Korur, 2014; Çetin, & Özdemir, 2018).

The conclusion of the analysis of teachers' lesson presentation after intervention

In conclusion, fourteen (14)out of the sixteen (16) teachers presented lessons considering students' prior knowledge and their lessons being learner-centred as compared to where no one did that before interventions. Even though two (2) of the teachers still used the teacher-centred strategy after the intervention it is insignificant as compared to thirteen (13)out of the sixteen (16) teachers who used teacher-centred strategy before the intervention.

Question 5: What do you want your learners to learn when developing this lesson?

Before intervention

Table 4.10: Teachers' responses to the objectives of developing a lesson on current electricity, before intervention

Description	Excerpt of teacher	Frequency N = 16
Developing knowledge base	E1: 'at the end of the lesson learners will be able to learn the significance of electricity in their homes and find the cost of usage of electric current usage'	7
Develop problem-solving skills	F2: 'I want them to acquire problem-solving skills and be able to use their creative and creative think skills effectively'	6
Developing collaborative skills	G2: 'Problem-solving skills and Language usage'	1
No response		2

Developing a knowledge base

As depicted in Table 4.10, eight (8) out of the sixteen (16) respondents indicated that their objectives of preparing the lesson on current electricity are to develop the acquisition of subject matter content on electricity. These teachers' objective of developing the lesson aligns with the objectives of developing a lesson when using the problem-based learning (PBL) strategy. This claim is consistent with the views of Beringer (2007), who stated that one of the objectives of developing a lesson when using the problem-based learning (PBL) strategy is to construct an extensive and flexible knowledge base. Furthermore, the claim by these teachers and Beringer (2007) also supports the objective of teaching physics based on the CAPS document. The South African curriculum of basic education states that the objectives of teaching Physical Science is for students to develop relevant skills such as classifying, communicating, measuring, designing an investigation, drawing and evaluating conclusions, formulating models, hypothesizing, identifying and controlling variables, inferring, observing and comparing, interpreting, predicting, problem-solving and

reflective skills (Department of Basic Education (DBE), 2011b). The response of teacher E1 is represented in Table 4.10.

Develop problem-solving skills

In addition, six (6) other teachers' objectives of developing the lesson on current electricity are to develop in students' problem-solving skills (Table 4.10). Again, these teachers' objective aligns with the problem-based learning (PBL) strategy. The claim is consistent with the views of Beringer (2007) who stated that one of the main objectives of developing a lesson when using the problem-based learning (PBL) strategy is to develop in students effective problem-solving skills and is also affirmed by the Department of Basic Education (DBE) (2011b) Curriculum Assessment and Policy Statement (CAPS) Physical Science document.

Developing collaborative skills

Furthermore, researchers have affirmed that developing collaboration in students is an important objective when using the problem-based learning (PBL) strategy (Beringer, 2007). This claim is affirmed by teacher G2 when he stated that his objective of developing the lesson is to develop in problem-solving skills and language usage in the learners (4.10). The claim is also consistent with the Department of Basic Education (DBE) (2011b) Curriculum Assessment and Policy Statement (CAPS) Physical Science.

Unfortunately, two teachers from the sample space did not respond to the question, which possibly means that they have no knowledge of the objectives of developing a lesson in current electricity.

The conclusion of the analysis of what teachers want students to learn when developing a lesson, before intervention

It could be concluded that teachers have knowledge of the objectives of developing a lesson using the problem-based learning (PBL) strategy since fourteen (14) out of the sixteen (16) teachers indicated objectives that were aligned with the problem-based learning (PBL) strategy. However, teachers may need an intervention to be introduced to the other two objectives of problem-based learning (PBL) strategy as per Beringer (2007); promoting self-directed learning and developing intrinsic motivation.

After intervention

Table 4.11: Teachers' responses to the objectives of developing a lesson on current electricity, after intervention

Description	Excerpt of teacher	Frequency N = 16
Developing knowledge base	B2: 'To increase the understanding and acquisition of the subject matter, enhanced learners thinking skills, improve problem-solving skills'	5
Develop problem-solving skills	C2: 'To develop the skills in solving real-life problem'	7
Developing collaborative skills	'I want my learners to develop the skills in communicating, be able to use their creative skills in solving day to day problems'	2
Promoting self-directed learning	F1: 'develop problem-solving and ability to learn on their own'	1
Developing intrinsic motivation	H2: 'I want my learners to learn how they can learn without a teacher, be able to love the subject and learn it at all times'	1

It emerges from Table 4.11 that, after the intervention, all the teachers from the sample space demonstrated a good knowledge of the objectives of developing a lesson when applying the problem-based learning (PBL) strategy as in the following areas; developing an extensive knowledge base, developing effective problem-solving skills, developing collaborative skills, promoting self-directed learning and developing intrinsic motivation. This is consistent with the views of Beringer (2007) and affirmed by the Department of Basic Education (DBE) (2011b) Curriculum Assessment and Policy Statement (CAPS) Physical Science as stated earlier in the section, before the intervention.

The conclusion of the analysis of what teachers want students to learn when developing a lesson, after intervention

In conclusion, all the teachers from the sample space demonstrated knowledge of the objectives of developing a PBL lesson. Therefore, the analysis indicates that teachers had gained knowledge of the objectives of developing a lesson to implement the problem-based learning (PBL) strategy.

Question 6: *How would you know your learners understand the topic?*

Before intervention

Table 4.12: Teacher' responses to how they would know whether their learners have understood the lesson on current electricity, before intervention

Description	Excerpt of teacher	Frequency N = 16
Applied competencies	F1: 'When they are able to apply the knowledge learnt to solve problems of life'	9
Critical thinking and problem-solving	G1: if they are able to solve problem related to electricity given to them using their critical thinking skills	4
Collaborative and leadership competency		0
No response		3

Applied competencies

The analysis as depicted in Table 4.12 reflect that nine (9) out of the sixteen (16) teachers indicated that they can know their students understand the topic on electricity when they are able to apply the knowledge, skills, and ability to solve problems of life. This claim is consistent with the views of McParland, Noble, & Livingston, (2004) in saying that one way to know whether students have understood a lesson is when they

are able to demonstrate mastery of how to organize a concept, analyse variables and identify a learning issue. The claim of teacher F1 is represented in Table 4.12 above.

Critical thinking and problem-solving

Similarly, critical thinking to solve the problem of life is one way to ascertain the fact that students have learned a concept (McParland et al., 2004). This claim is consistent with the views of teacher G1 when she indicated that she would know if the learners have understood the lesson if they solve problems related to electricity using their critical thinking skills (Table 4.12).

The conclusion of the analysis of teachers' assessment of students' understanding of a topic, before intervention

In conclusion, three (3) out of the sixteen (16) teachers did not answer the question. However, thirteen (13) of them answered the question focusing on students' applied competencies, critical thinking skills, and problem-solving skills. No teacher from the sample space answered the question using collaborative skills and leadership competencies. However, as set out by McParland et al. (2004), three main areas can be used to check whether students have understood a lesson;

1. applied competencies, where they are expected to demonstrate mastery of how to organize a concept, analyse variables and identify a learning issue,
2. critical thinking skills and problem-solving skills
3. Collaborative and leadership competency.

It is therefore important for teachers to be provided with interventions to equip the student's with collaborative skills and leadership competencies to assess whether they have understood a lesson.

After intervention

Table 4.13: How teachers would know whether their learners have understood the lesson on current electricity, after intervention

Description	Excerpt of teacher	Frequency N = 16
Applied competencies	C2: 'By asking questions and getting correct answers. Apply their skills to solve class work and homework question after the lesson'	5
Critical thinking and problem-solving	B2: 'When they are able to give answers to the given problem'	8
Collaborative and leadership competency	A2: 'when they use electricity wisely, and when they check and play the role in community to report and advise against bad influence and practices'	3

After the intervention, five (5) out of the sixteen (16) teachers used students' applied competencies to check if whether they had understood a lesson (Table 4.13). Eight (8) other teachers from the sample use students' critical thinking skills and problem-solving skills (Table 4.13). While three (3) of them use students' collaborative and leadership competencies (Table 4.13). All these claims are consistent with the views of McParland et al. (2004) when they started their three main methods for establishing whether students have understood a lesson (section before intervention question 6).

The conclusion of the analysis of teachers' assessment of students' understanding of a topic, before intervention

From the analysis above, all the teachers from the sample space have demonstrated knowledge of PBL assessment. This clearly shows that teachers have gained knowledge of how to verify students' understanding of a lesson.

4.3.3 Teachers' reflection on PBL, after the intervention

Two questions from the Q2AI were used to assess teachers' feelings concerning the professional development intervention.

Question 1: Briefly explain what you liked or disliked in the workshop?

Table 4.14: Teachers' responses to a question concerning their feelings about the intervention workshop

Description	Excerpt of teacher	Frequency N = 16
Like the workshop	A2: 'it was very long but formative and interesting' E2: 'it was interesting to work in groups although the different levels of understanding of the application of PBL turned to be problematic' G2: 'during the workshop, I was able to meet with other teachers from other schools' H1: 'the fact that the workshop clearly explains how to go about when introducing a lesson to learners and it clearly outlines the processes of problem-based learning'	14
Dislike the workshop		0
No response		2

Like the workshop

It is clear from Table 4.14 that fourteen (14) out of the sixteen (16) teachers indicated positive feelings about the intervention workshop. Some indicated that it was informative and interesting. This claim was consistent with the views of Hassel (1999) by stating that the significance of professional development is to get teachers informed of new things. Furthermore, teachers experience PBL when they expressed positive feelings when they work in groups and develop a friendship when they meet with other teachers (Table 4.14). Han, Capraro and Capraro (2015) are convinced that the idea of working together in a group is one of the fundamentals of PBL.

Dislike the workshop

From the results of the analysis, no teacher from the sample space expressed negative feelings about the workshop (Table 4.14). However, two teachers did not respond to the question which could probably mean that they have a negative feeling.

The conclusion of the analysis of teachers' feelings about PBL, after the intervention

In conclusion, fourteen (14) out of the sixteen (16) teachers expressed positive attitude after the intervention which means that they are positive to implement the strategy in their physics classrooms.

Question 2: Will you use the PBL approach in your classroom? If yes, why and if no, why not.

Table 4.15: Teachers' responses to whether or not they would use the PBL strategy

Description	Excerpt of teacher	Frequency N = 16
Like to use PBL	B1: 'I would like to use the PBL approach in my physics class. It can help improve learners' problem-solving skills' A1: 'Yes, it can promote teamwork within my learners. Each learner will have a duty in their groups and that will give them responsibility. They will be dealing with real-life problems and will, therefore, sharpen their minds'	13
Dislike to use PBL	A2: 'No, I will not use it because it will use a lot of time, is difficult to write the driving question'	3

Like to use PBL

Researchers have affirmed that PBL develops problem-solving skills and promotes teamwork. This is affirmed by Ferreira and Trudel, (2012) who support PBL since it develops problem-solving skills. Furthermore, Terry Barrett (2010) supports the PBL

strategy since it enhances the relevance of working together, friendships and belongingness. These researchers claim to support the claim by teacher B1 and A1 in Table 4.15.

Dislike to use PBL

On the contrarily, three (3) teachers held the view that PBL is time-consuming and difficult to develop the driving question (Table 4.15). This claim is affirmed by Kolmos (2017) who stated that one of the disadvantages of PBL is that it is time-consuming.

The conclusion of the analysis of teachers' opinions regarding whether or not to use the PBL strategy

In view of the above, it can be concluded that thirteen (13) out of the sixteen (16) teachers prefer to use the PBL strategy to teach their physics students. This probably could mean that thirteen (13) teachers are ready to implement the strategy in their physics classrooms.

4.4 DATA ANALYSIS AND INTERPRETATIONS OF THE LESSON OBSERVATIONS

All 16 participating teachers were observed for at least one hour in their physics classes before the intervention and during the implementation of the PBL strategy. The key areas as stated in the RTOP and which form the five themes of the study are (Appendix F):

1. lesson plan and implementation
2. propositional content knowledge
3. procedural content knowledge
4. classroom culture (communicative interactions)
5. classroom culture (teacher/student or student/student interaction)

A scale of 0 to 4 was used to rate and interpret the performance of teachers in each criterion during the observation scheduled. The interpretations of the rating scale are 0 – no, 1 – low, 2 – moderate, 3 – high and 4 – very high. Tables 4.1 and 4.2 show the representations of the data collected during the classroom observations.

4.4.1 Lesson plan and implementation

Table 4.16: Data collected on the lesson plan and implementation during observation, prior to intervention

Criteria	Rating of teachers' performances 0 to 4						
		no	low	Mode-rate	high	very high	Total
		0	1	2	3	4	
LESSON PLAN AND IMPLEMENTATION							
Instructional strategy and activity respect students' prior knowledge and the preconceptions inherent therein	n	10	6	0	0	0	16
	%	62	38	0	0	0	100
The lesson was designed to engage students as members of a learning community	n	12	4	0	0	0	16
	%	75	25	0	0	0	100
In this lesson students' exploration preceded formal presentation	n	16	0	0	0	0	16
	%	100	0	0	0	0	100
This lesson encourages students to seek and value alternative modes of investigation and of problem-solving	n	16	0	0	0	0	16
	%	100	0	0	0	0	100
The focus and direction of the lesson was often determined by ideas originating from students	n	16	0	0	0	0	16
	%	100	0	0	0	0	100

Table 4.17: Data collected on lesson plan and implementation during observation, after intervention

Criteria		Rating of teachers' performances 0 to 4					
		no	low	moderate	high	very high	Total
		0	1	2	3	4	
LESSON PLAN AND IMPLEMENTATION							
Instructional strategy and activity respect students' prior knowledge and the preconceptions inherent therein	n	0	0	10	6	0	16
	%	0	0	62	38	0	100
The lesson was designed to engage students as members of a learning community	n	0	0	4	12	0	16
	%	0	0	25	75	0	100
In this lesson students' exploration preceded formal presentation	n	0	3	0	13	0	16
	%	0	19	0	81	0	100
This lesson encourages students to seek and value alternative modes of investigation and of problem-solving	n	0	0	0	9	7	16
	%	0	0	0	56	44	100
The focus and direction of the lesson was often determined by ideas originating from students	n	0	0	3	9	4	16
	%	0	0	19	56	25	100

Instructional strategy respecting students' prior knowledge

Table 4.16 summarises that, before the intervention, ten (10) out of the sixteen (16) teachers presented their lesson without making a link between the students' prior knowledge and the new topic. However, six (6) teachers demonstrated this but at a low level. This confirmed the claim in section 4.3.2 question 4 before intervention that seven (7) out of the sixteen (16) teachers presented a lesson without considering students' prior knowledge. However, after the intervention, all the teachers in the sample observed, linked student prior knowledge to the new concept during their presentation; ten (10) out of the sixteen (16) respondents demonstrated moderately and six (6) demonstrated highly (Table 4.17).

A lesson designed to engage students to work together in groups

On the other hand, before the intervention, twelve (12) out of the sixteen (16) teachers did not engage students as groups in a learning community, though four (4) of them

involved students at a very low level (Table 4.16). However, after the intervention, students were observed working in groups and sharing ideas. From the analysis, twelve (12) out of the sixteen (16) teachers showed a high level of students engaging in the class as students studying together and four (4) demonstrated a moderate level of engagement (Table 4.17).

In this lesson, the students' exploration preceded the formal presentation

Unfortunately, the lessons presented by all the sampled teachers before the interventions did not grant students the opportunity of exploring and presenting their findings but the teacher rather presented the lesson without any involvement from the students (Table 4.16). However, after the interventions, thirteen (13) out of the sixteen (16) teachers engaged their students to explore an ill-structured problem presented to them (Table 4.17).

Encouraging alternative modes of investigation and of problem-solving

Furthermore, before the intervention, no teachers were encouraging students to seek alternative modes of investigation (Table 4.16). However, after the intervention, in schools F and H, students were observed criticizing their friend's solution and coming up with a new solution that was accepted by the group. This means that students value alternative solutions to problems. From the analysis, nine (9)out of the sixteen (16) teachers highly encouraged students to seek an alternative mode of investigating a problem and seven (7) encouraged them very highly (Table 4.17), after the intervention.

Focus and direction of lesson determined by ideas originating from students

Before the interventions and in all the sampled teachers' presentations, the focus and direction of the lesson were not determined by ideas created by students but rather the teacher determined the directions of the lesson (Table 4.16). However, after the intervention, nine (9)out of the sixteen (16) respondents teachers highly valued students' ideas to determine the directions of the lesson, four (4) moderately valued the skill and three (3) valued the skill very highly (Table 4.17). This shows that all the teachers encouraged students' ideas to determine the effort and direction of the lesson.

The teachers used the lecture method to teach before the intervention and the consequence of it is that students may probably not be able to develop problem-solving skills, critical thinking skills, and motivation. Researchers have affirmed that research-based active teaching methods are suitable for teaching science and mathematics (Lujan & DiCarlo, 2006). The PBL strategy which is a one-stop teaching strategy has the advantage of promoting communication skills through collaboration (Krajcik, McNeill, & Reiser, 2008) and develops in students the skills needed to live successfully in the 21st-century society.

4.4.2 Propositional content knowledge

Table 4.18: Data collected on teachers' propositional content knowledge during observation, prior to intervention

Criteria		Rating of teachers' performances 0 to 4					
		no	low	moderate	high	very high	Total
		0	1	2	3	4	
CONTENT (PROPOSITIONAL KNOWLEDGE)							
The lesson involved fundamental concepts of the subject	n	0	5	7	4	0	16
	%	0	31	44	25	0	100
The lesson promoted strongly coherent conceptual understanding	n	0	12	4	0	0	16
	%	0	75	25	0	0	100
The teacher had a solid grasp of the subject matter content inherent in the lesson	n	0	5	5	6	0	16
	%	0	0	31	31	38	100
Element of abstraction was encouraged where it was important to do so	n	16	0	0	0	0	16
	%	100	0	0	0	0	100
Connections with other content disciplines or real-world phenomena were explored and valued	n	13	3	0	0	0	16
	%	81	19	0	0	0	100

Table 4.19: Data collected on teachers' propositional content knowledge during observation, after intervention

Criteria		Rating of teachers' performances 0 to 4					
		no	low	moderate	high	very high	Total
		0	1	2	3	4	
CONTENT PROPOSITIONAL KNOWLEDGE)							
The lesson involved fundamental concepts of the subject	n	0	0	9	7	0	16
	%	0	0	56	44	0	100
The lesson promoted strongly coherent conceptual understanding	n	0	0	7	9	0	16
	%	0	0	44	56	0	100
The teacher had a solid grasp of the subject matter content inherent in the lesson	n	0	6	4	6	0	16
	%	0	0	63	37	0	100
Element of abstraction was encouraged where it was important to do so	n	0	4	8	4	0	16
	%	0	25	50	25	0	100
Connections with other content disciplines or real-world phenomena were explored and valued	n	0	0	10	6	0	16
	%	0	0	62	38	0	100

A lesson involving the fundamental concepts of the subject

Considering the evidence collected prior to the intervention, five (5)out of the sixteen (16) teachers presented a lesson demonstrating a low level of the fundamental concept of the subject, seven (7) teachers showed a moderate level and four (4) teachers showed a high level (Table 4.18). However, after the intervention, nine (9) out of the sixteen (16) teachers presented a lesson demonstrating a moderate level of the fundamental concept of the subject and seven (7) showed a high level (Table 4.19).

Based on the evidence above it implies that all the teachers observed before and after the intervention demonstrated a good level of content knowledge. This is probably due to the fact that all teachers in the cluster have strong academic background as confirmed in section 4.2.4

Lesson promotes strong coherent conceptual understanding

In another development, all the presentations of the teachers were observed to promote some level of conceptual understanding prior to the intervention. It was noted that twelve (12)out of the sixteen (16) teachers' presentations promote low conceptual understanding and four (4) teachers' presentations promote moderate conceptual understanding (Table 4.18). This signifies that before interventions, a high proportion of students do not easily understand the concept being taught. However, during the use of the PBL strategy in class after the interventions, it was observed that seven (7)out of the sixteen (16) teachers presented a lesson that moderately promoted a strong conceptual understanding and nine (9) of them presented lessons that promoted a high level of conceptual understanding (Table 4.19).

Teachers' understanding of the subject matter content inherent in the lesson

Furthermore, all the sampled teachers demonstrated some level of understanding of the physics concept, prior to the intervention (Table 4.18). In view of this, five (5) out of the sixteen (16) teachers demonstrated a moderate understanding of the physics concept, another five (5) teachers showed a high understanding and six (6) teachers demonstrated a very high level of understanding (Table 4.18). However, during implementation, most of the teachers demonstrated very good knowledge of content delivery. Ten (10)out of the sixteen (16) teachers demonstrated a moderate level of understanding of subject matter content and six (6) teachers demonstrated a high level (Table 4.19).This therefore suggests that all the teachers have adequate knowledge of the subject matter content. This is probably due to the fact that all teachers teaching Physical Science at Entsikeni cluster have strong academic background as confirmed in section 4.2.4. Rice (2013) highlighted the positive effect of teachers' academic background on students' achievement.

However, teachers demonstrated a better grasp of subject matter content in the lessons before the introduction of the PBL strategy than during the implementation of the strategy. This could probably be due to the differences in the teaching method. Before the implementation of the PBL strategy, teachers were observed using the lecture method where students sat down in their chairs and teachers transmitted knowledge to them. In the PBL class, the teacher only acted as a facilitator allowing students to explore their own learning.

Connections with other content disciplines or real-world phenomena were explored and valued

Given the evidence gathered in Table 4.19, thirteen (13) out of the sixteen (16) teachers prepared a lesson which had no connection with other subjects, prior to the intervention. The reason for this could be that teachers had no experience in using an interdisciplinary approach to teaching physics such as STEM which integrates science, technology, engineering, and mathematics. This confirms the claim in section 4.2.3 that twelve (12) out of the sixteen (16) respondents are inexperienced in teaching physics in the FET. After the intervention and during the implementation period teachers in the PBL class were observed encouraging students to make connections with other content from other subjects or real-world phenomena during their exploration. It can therefore be concluded that teachers have demonstrated a good propositional content knowledge in PBL, after the intervention.

4.4.3 Teachers' procedural content knowledge during lesson delivery

Table 4.20: Data collected on teachers' procedural content knowledge during observation, prior to intervention

Criteria		Rating of teachers' performances 0 to 4					
		no	low	moderate	high	very high	Total
		0	1	2	3	4	
CONTENT (PROCEDURAL KNOWLEDGE)							
Students used a variety of means (models, drawings, graphs etc.) to represent phenomena	n	10	6	0	0	0	16
	%	62	38	0	0	0	100
Students made predictions, and/or formulated hypotheses and devised means for testing them	n	16	0	0	0	0	16
	%	100	0	0	0	0	100
Students were actively engaged in thought-provoking activity often involved critical assessment of procedures	n	13	3	0	0	0	16
	%	81	19	0	0	0	100
Students were reflective about their learning	n	16	0	0	0	0	16
	%	100	0	0	0	0	100
Intellectual rigour, constructive criticism, and the challenging of ideas were valued	n	12	4	0	0	0	16
	%	75	25	0	0	0	100

Table 4.21: Data collected on teachers' procedural content knowledge during observation, after intervention

Criteria		Rating of teachers' performances 0 to 4					
		no	low	moderate	high	very high	Total
		0	1	2	3	4	
CONTENT (PROCEDURAL KNOWLEDGE)							
Students used a variety of means (models, drawings, graphs etc.) to represent phenomena	n	0	0	9	7	0	16
	%	0	0	56	44	0	100
Students made predictions, and/or formulated hypotheses and devised means for testing them	n	0	0	4	9	3	16
	%	0	0	25	56	19	100
Students were actively engaged in thought-provoking activity that often involved critical assessment of procedures	n	0	0	13	3	0	16
	%	0	0	81	19	0	100
Students were reflective about their learning	n	0	5	8	3	0	16
	%	0	31	50	19	0	100
Intellectual rigour, constructive criticism, and the challenging of ideas were valued	n	0	3	7	6	0	16
	%	0	19	44	38	0	100

Students using various means to represent phenomena

Evidence before the intervention show that ten (10)out of the sixteen (16) teachers were not giving students the opportunity of willingly representing phenomena using models, drawings, graphs etc., but six (6) guided students at a low level (Table 4.20). However, after the intervention, seven (7) out of the sixteen (16) teachers guided students to use models, drawings; graphs etc. to represent phenomena at a high level and nine (9) guided them at a moderate level (Table 4.21). This signifies that teachers have improved tremendously in their procedural content knowledge in delivering a lesson after having experienced the PBL strategy.

Students made predictions, and/or formulated hypotheses and devised means for testing them

Furthermore, students formulating hypotheses and making predictions and devising means to test them is very important in the PBL process but before the intervention the teachers were not encouraging their students to do that (Table 4.20). It was observed that students only follow the teacher's presentations, copy notes and answer

questions from the teacher verbally as the lesson progresses. On the contrary, after the intervention and during the implementation of the PBL strategy, four (4) out of the sixteen (16) teachers were observed encouraging students at a low level to make predictions and formulate hypotheses. Nine (9) teachers were observed doing that moderately and three (3) of teachers doing it at a high level (Table 4.21). As a result, there was an improvement in teachers' lesson deliveries.

Students were actively engaged in thought-provoking activity that often-involved critical assessment of procedures

Research has shown that active involvement is very significant in PBL lesson delivery. However, thirteen (13) out of the sixteen (16) teachers were observed presenting lessons where students were not actively engaged in thought-provoking activity that involved critical assessment of procedures (Table 4.20). Only three (3) teachers involved students actively but at a low level (Table 4.20). But after interventions, it was observed that three (3) out of the sixteen (16) respondents demonstrated a high level of students' involvement in a thought-provoking activity that involved critical assessment of procedure, nine (9) of them demonstrated moderately and four (4) demonstrated at a low level (Table 4.21). This means that teachers have improved on their procedural content knowledge in delivering a lesson after the PBL intervention program.

Intellectual rigour, constructive criticism, and the challenging of ideas

As reflected in Table 4.20, evidence gathered before intervention show that twelve (12) out of the sixteen (16) teachers presented lessons where students were not encouraged to engage in criticizing and challenging their friends' ideas and make theirs as the lesson proceeds. However, four (4) teachers encouraged constructive criticism and challenging ideas at a low level. On the contrarily, when the teachers were observed during the implementation stage, six (6)out of the sixteen (16) teachers were highly encouraging students to challenge and criticize ideas, seven (7) teachers moderately encouraged students challenging and criticising and three (3) teachers encouraged students challenging and criticising at a low level (Table 4.21). This therefore indicates that teachers have improved in their procedural content knowledge in lesson delivery, after experiencing the PBL strategy.

4.4.4 Communicative interaction with students

Table 4.22: Data collected on teachers' communicative interaction with students during observation, prior to intervention

Criteria		Rating of teachers' performances 0 to 4					
		no	low	moderate	high	very high	Total
		0	1	2	3	4	
CLASSROOM CULTURE (COMMUNICATIVE INTERACTIONS)							
Students were involved in the communication of their ideas to others using a variety of means and media	n	12	4	0	0	0	16
	%	75	25	0	0	0	100
The teachers' questions triggered divergent modes of thinking	n	14	2	0	0	0	16
	%	87	13	0	0	0	100
There was a large proportion of student talk and a significant amount of it occurred between and among students	n	13	3	0	0	0	16
	%	81	19	0	0	0	100
Students' questions and comments often determined the direction and focus of classroom discourse	n	16	0	0	0	0	16
	%	100	0	0	0	0	100
There was a climate of respect for what others had to say	n	0	12	4	0	0	16
	%	0	75	25	0	0	100

Table 4.23: Data collected on teachers' communicative interaction with students during observation, after intervention

Criteria		Rating of teachers' performance 0 to 4					
		no	low	Mode-rate	high	very high	Total
		0	1	2	3	4	
CLASSROOM CULTURE (COMMUNICATIVE INTERACTIONS)							
Students were involved in the communication of their ideas to others using a variety of means and media	n	0	3	4	9	0	16
	%	0	19	25	56	0	100
The teachers' questions triggered divergent modes of thinking	n	0	3	6	7	0	16
	%	0	19	38	44	0	100
There was a large proportion of student talk and a significant amount of it occurred between and among students	n	0	2	6	8	0	16
	%	0	13	38	50	0	100
Students' questions and comments often determined the direction and focus of classroom discourse	n	0	0	4	9	3	16
	%	0	0	25	56	19	100
There was a climate of respect for what others had to say	n	0	0	5	11	0	16
	%	0	0	31	69	0	100

Students were involved in the communication of their ideas to others using a variety of means and media

The result of the analysis shows that, before the intervention, twelve (12) out of the sixteen (16) teachers presented a lesson where students were not involved in communicating their ideas to teachers or other students. Only four (4) teachers involved their students in communicating their ideas but at a low level (Table 4.22). In contrast, after intervention, nine (9)out of the sixteen (16) teachers in the sample demonstrated a high level of students' involvement in communicating their ideas, four (4) teachers encouraged moderately and three (3) teachers encouraged communication at a low level (Table 4.23). In school F1 students were using social media (WhatsApp) to communicate their ideas to other students. But in most cases, students were communicating their idea through pen and paper.

Teachers' questions triggered divergent modes of thinking

Research has proven that questioning is an effective tool to promote critical thinking skills in students but only two (2) out of the sixteen (16) teachers, prior to intervention, were observed to use questions to trigger divergent modes of thinking (Table 4.22). On the contrarily, after the intervention, it was observed that seven (7) teachers out of the sixteen (16) highly used questions to trigger divergent modes of thinking, six (6) teachers demonstrated it moderately and three (3) teachers demonstrated it at a low level (Table 4.23).

In school A, teacher A2 was observed using thought-provoking questions to trigger students to focus on their discussions. Teacher A's questions to the learners:

> *A2: 'If you could prove Ohm's law wrong, which factor would you use? Temperature or length of the conductor? Why?'*

A high proportion of student talk occurred between and among students

Furthermore, students talking among themselves promote collaborative skills. However, thirteen (13) out of the sixteen (16) teachers observed before intervention were teaching without promoting this important PBL skill among student (Table 4.22). However, during the implementation of the PBL strategy, all the teachers that were observed showed some level of encouragements of students' talk. Eight (8)out of the sixteen (16) teachers demonstrated this skill at a high level, six (6) teachers demonstrated it at a moderate level and two (2) teachers demonstrated it at a low level (Table 4.23).

Students' questions and comments often determine the direction and focus of classroom discourse

Before the intervention, none of the teachers gave attention to students' questions and comments during their presentation (Table 4.22). For instance, in school A when the teacher was busy explaining the relationship between resistance, current, and voltage, as well as the Ohm's law one student asked;

> *Student: 'Sir, when the temperature is high, what happens to the resistance of a wire?'*

Unfortunately, this question was left unanswered and the lesson continued with calculations on combined resistors in series and in parallel. Obviously, classroom proceedings were dominated by the teacher and the students' questions do not determine the directions of the class discussions.

However, after the intervention, three (3) out of the sixteen (16) teachers used students' question very highly to determine the direction and focus of the class discussion, nine (9) used it highly and four (4) used questions moderately to determine the direction of class discussions (Table 4.23). All the teachers encouraged students to ask questions and make comments of proceedings which often determined the direction and focus of class discussions.

4.4.5 Classroom culture teacher/student relationship in the teaching and learning process

Table 4.24: Data collected on classroom culture teacher/student relationship during observation, prior to intervention

Criteria		Rating of teachers' performances 0 to 4					
		no	low	moderate	high	very high	Total
		0	1	2	3	4	
CLASSROOM CULTURE (TEACHER-STUDENT RELATIONSHIP)							
Active participation of students was encouraged and valued	n	14	2	0	0	0	16
	%	87	13	0	0	0	100
Students were encouraged to generate conjectures, alternative solution strategies and ways of interpreting evidence	n	16	0	0	0	0	16
	%	100	0	0	0	0	100
In general, the teacher was patient with students	n	0	3	6	7	0	16
	%	0	19	37	44	0	100
The teacher acted as resource person, working to support and enhance students' investigation	n	12	4	0	0	0	16
	%	75	25	0	0	0	100
The metaphor as listener was very characteristic to this classroom	n	8	8	0	0	0	16
	%	50	50	0	0	0	100

Table 4.25: Data collected on classroom culture teacher/student relationship during observation after intervention

Criteria		Rating of teachers' performance 0 to 4					
		no	low	moderate	high	very high	Total
		0	1	2	3	4	
CLASSROOM CULTURE (TEACHER-STUDENT RELATIONSHIP)							
Active participation of students was encouraged and valued	n	0	0	6	10	0	16
	%	0	0	38	62	0	100
Students were encouraged to generate conjectures, alternative solution strategies and ways of interpreting evidence	n	0	0	3	13	0	16
	%	0	0	19	81	0	100
In general, the teacher was patient with students	n	0	0	4	12	0	16
	%	0	0	25	75	0	100
The teacher acted as resource person, working to support and enhanced students' investigation	n	0	0	10	6	0	16
	%	0	0	62	38	0	100
The metaphor as listener was very characteristic of this classroom	n	0	0	11	5	0	16
	%	0	0	69	31	0	100

Active participation of students was encouraged and valued

Prior to interventions, fourteen (14) out of the sixteen (16) respondents presented lessons during which students were not actively participating. However, two (2) teachers encouraged active participation at a low level (Table 4.24). After the intervention, ten (10)out of the sixteen (16) teachers encouraged active involvement of students at a high level and six (6) teachers encouraged participation moderately (Table 4.25).

Students are encouraged to generate conjectures, alternative solution strategies and ways of interpreting evidence

None of the teachers, prior to intervention, encouraged students during their lessons to make conjectures or give alternative solutions to problems (Table 4.24). However, after the intervention, thirteen (13) out of the sixteen (16) teachers highly encouraged students to make conjectures give an alternative solution to problems and ways of

interpreting evidence. On the other hand, three (3) teachers did this moderately (Table 4.25).

Teachers' patience with students

In another development, when teachers were observed regarding their patience with students before interventions, seven (7) out of the sixteen (16) teachers showed a high level of patience with students, six (6) teacher's demonstrated moderate patience with students, and three (3) teachers showed patience at a low level (Table 4.24). On the contrary, thirteen (13) out of the sixteen (16) teachers demonstrated a high level of the patience and three (3) teachers a very high level of patience (Table 4.25).

Teacher acted as a resource person, working to support and enhance students' investigation

Prior to intervention, twelve (12) out of the sixteen (16) respondents could not act as resource persons to support students' investigation but acted as resource persons to spoon-feed students with information (Table 4.24). On the other hand, six (6) out of the sixteen (16) respondents highly demonstrated the skill as a resource person to support and enhance students' investigation and ten (10) teachers demonstrated the skill moderately (Table 4.25).

4.4.6 Summary of the lesson observation

In conclusion, as recorded above in the analysis from section 4.3.1, it becomes clear that when teachers were asked to indicate their preferred teaching strategy with reasons, most of the teachers indicated that they prefer the following active teaching strategies; problem-solving, demonstration, discussions, inquiry-based, question and answer method. Only two teachers indicated that they prefer the lecture method. However, when teachers were observed in their classrooms, prior to the intervention, the data collected signified that all the teachers used the traditional lecture instructional strategy (section 4.4). This means that teachers' preferred teaching strategy was not the one they used in the classroom. This could probably mean that although they prefer the active teaching methods, they are not comfortable in using them in their class. During the lesson observation before the intervention program, it was observed that:

1. Most of the teachers were using the traditional lecture method to teach physics (see sections 4.4.1)
2. Students were not actively involved in the teaching and learning process (see section 4.4.5)
3. The direction and focus of the lessons were solely determined by the teacher and not by the ideas originating from students
4. Students' exploration was not encouraged and therefore the ability to learn on their own could possibly not be advanced (see section 4.4.1).
5. Students were not given the opportunity to connect other content disciplines and real-world phenomena, which means interdisciplinary approach to teaching was not applied (see section 4.4.2)
6. Teachers were not engaging students in thought-provoking activities that could possibly improve their critical thinking skills (see section 4.4.3)
7. Students were not encouraged to make predictions or formulate hypotheses to improve their problem-solving skills (see section 4.4.3).
8. Teachers could not help students to form collaborative skills by encouraging collaborations among students (see section 4.4.4).
9. Students were not encouraged to generate conjectures, alternative solution strategies and ways to interpret evidence to improve their problem-solving and critical thinking skills (see section 4.4.5)

Consequently, the effect of the above teaching practices on the students could be that:

1. Students would lack problem-solving and critical thinking skills
2. Students would lose interest and motivation to learn physics
3. Students would lack understanding and acquisition of subject matter knowledge
4. Concepts learned cannot be retained longer
5. Students would lack interpersonal skills and communication skills.
6. Students would lack self-directed learning
7.

However, from the analysis, it was obvious that teachers' teaching practices had changed after the intervention and during the implementation of the PBL strategy. In

general, teachers' lesson delivery improved in the following areas: engage students actively, encourage students' explorations, encourage student's alternative mode of investigation and problem-solving (see section 4.4.1). Again, teachers were observed presenting lessons involving students using different means to represent a phenomenon, students making predictions and formulating hypotheses, students involving in thought-provoking activities and students engaging in constructive criticism and challenging of ideas were proved (see section 4.4.3). Finally, teachers' lesson presentations after intervention encouraged students to communicate their ideas (see section 4.4.4) and encouraged them to make conjectures and develop alternative solutions and strategies (see section 4.4.5)

4.5 INTERVIEW DATA ANALYSIS AND INTERPRETATION

This section reports on the results on data collected from the semi-structured interviews (see Appendix E) conducted with Physics teachers at the Entsikeni cluster in the Harry Gwala district during the study. The aim of the interview was simply to provide in-depth knowledge on teachers' experiences while implementing the PBL strategy. This add on to the various information collected qualitatively on teachers' understanding of PBL prior to and after intervention and how teachers implemented PBL in their classrooms.

4.5.1 Teachers' experiences while implementing the PBL strategy

The section consists of seven questions (see Appendix E). Question 1.1 was merged with question 1 in section 4.3.2 as they are similar and carried the same responses from respondents. Also questions 1.3, 1.4, 1.5, 1.6 and 1.7 were merged together and discussed in section 4.5.1.2 since they all deal with the added values of PBL.

4.5.1.1 Appropriateness of introducing the PBL strategy in the physics classroom

Table 4.26: Teachers' responses to appropriateness to apply PBL to teach physics

Descriptions	Teacher's Excerpt	Frequency N=8
Appropriate	D1: 'has helped improve learners problem-solving skills'	3
Inappropriate	E1: 'teachers won't finish their ATP' G1: 'it is time-consuming' H1: 'difficult to write an ill-structured problem '	5

Three teachers out of the eight interviewed indicated that physics should be taught using the PBL strategy with reasons that it improves problem-solving skills. This claim is consistent with the views of Terry Barrett (2010) stating that in the PBL lesson, students are actively engaged in the teaching and learning process, and this turns to improve their problem-solving skills, enhances their thinking skills and creates positive attitude and motivation in them. The response of teacher D1 can be found in Table 4.26 above.

On the contrary, five teachers indicated that is inappropriate with reasons that it is time-consuming; teachers cannot finish their ATP, difficult to write an ill-structured problem. Kolmos (2017, p. 6) pointed out that the timeframe in which to complete a PBL module is often so short that it is not possible for students to learn the added values of PBL in such short space of time. This submission supports the teachers' claim as indicated in Table 4.26 above.

Summary of teacher experiences applying PBL

From the evidence obtained, it is likely that most of the sample teachers at Entsikeni cluster may not continue to apply the PBL strategy since five (5)out of the eight (8) interviewed have indicated that it is inappropriate to apply the PBL strategy since it is time-consuming, difficult to complete ATP and to develop an ill-structured problem.

4.5.1.2 The impact of the added values of PBL on students' learning after having been taught with the PBL strategy.

Table 4.27: Teachers' responses to changes in students' problem-solving skills, self-directed learning skills, retention ability, interest and motivation in physics after PBL

Descriptions	Teacher's Excerpt	Frequency N=8 for each criterion
Students problem-solving skills after PBL	A1: 'way of thinking about a problem has improved'. D1: 'Learners problem-solving skills were enhanced'. B2: 'Yes, I agree because their way of approaching a problem looks different now' F1: 'I agree the PBL improve problem-solving skills since learners can now associate academic and real-life problems' C1: 'I agree that it improves problem-solving skills if implemented well'	5
	G1: 'No significant change in learners' problem-solving skills' H1: 'I could not apply the method fully to realise a change in learners' performance because learners could not follow the process as required, time was a problem, other teachers were thinking their period are used' E1: 'I disagree because I didn't see a change in my learner's problem-solving skills'.	3
Students self-directed learning skills after PBL	D1: 'In my opinion, the creation of a positive attitude and motivation in learners stimulated them to learn on their own'. E1: 'The step of PBL where learners must do research has help learners to learn or get	8

	information about a problem with less or no help and this helps them to develop the ability to learn on their own'. F1: 'During the implementation, the groups met at their own times without a teacher forcing them because they had the passion and interest to work on their own. I believe if they continue learners will transfer the habit of wanting to learn on their own even to other subjects'.	
Students retention ability after PBL	A1: 'Learners are able to apply the concept to solve the problem more easily with PBL and recall what is learned easily than the traditional method'. C1: 'I believe if implemented effectively, it will enhance their retention ability because they were actively engaged in the learning process with the PBL approach'.	7
	H1: 'There was no significant difference in learner retention when taught with the PBL approach compare to the traditional method'.	1
Students interest and motivation in physics after PBL	A1: 'Learners were highly motivated when taught with the PBL approach than the traditional method because learners at this stage will always want to do things by themselves and show others what they can do'. C1: 'The PBL approach has created a positive attitude and motivation in learning physics in learners' B2: 'Learners have developed interest in learning. They fall in their own groups to research even at their own time'.	8

Inferred from the analysis, five (5) out of the eight (8) teachers interviewed were of the view that students' problem-solving skills had improved considering before and after

with the PBL strategy. Research has affirmed that students in PBL classrooms tend to have their problem-solving skills improved and subsequently develop their critical thinking skills as compared to those in the traditional lecture classrooms (Barrows & Tamblyn, 1980; Krajcik & Czerniak, 2014). This supports the teachers' claims which are indicated in Table 4.27 above. However, three other teachers differ by saying that they did not realise a change in students' problem-solving or critical thinking skills and therefore disagree that PBL improves problem-solving skills. Obviously, it was not part of the study to assess a change in students' knowledge and these teachers may be right if they did not conduct an assessment before and after the implementation. The claims of these teachers are indicated in Table 4.27.

Furthermore, five (5) out of the eight (8) teachers interviewed held the view that PBL has instilled in their learners the ability to study on their own (Table 4.27). They argue that it created a positive attitude and motivation in them, it stimulates them to meet and work on their project even after school. Subsequently, students became responsible for their studies. This links up with the social constructivists' claim that students are responsible for their learning, constructing and reconstructing their understanding even in the absence of complete information (Von Glasersfeld, 2013). This claim is affirmed by Surif, Ibrahimb and Mokhtarc, (2013) who also stated that when students are taught with the PBL strategy, motivation, engagement, and self-directed learning are enhanced once learners realise that they are responsible for their own learning. In a similar view, three teachers indicated that students meet on their own and do research to gather information on a problem, they do it with minimal guidance or no guidance at all and as such, they learn to learn on their own. This claim is consistent with the views of Terry Barrett (2010) who indicated that in a study when people were asked about the importance of PBL they indicated that it inculcates in learners how to learn on their own. The comments by teacher D1, E1 and F1 are represented in Table 4.27

In addition, the results of the analysis show that, seven (7) out of the eight (8) teachers interviewed claimed students can apply the concept to solve problem more easily and recall what they have studied more easily as compared to the traditional method of teaching (Table 4.27). They further indicated that if the strategy is implemented effectively, it will enhance students' retention ability and cited a reason that students

are actively engaged in the teaching and learning process and as such could make them retain longer what they have learned (Table 4.27). Surif et al., (2013) supports the view that when students feel responsible for their learning, motivation, engagement, self-directed learning and retention ability are enhanced. Terry Barrett (2010) supported Surif et al., (2013) and the teachers when he stated that in the PBL classroom, concepts learned are retained much longer and as such improve students' retention ability than is the case with the traditional lecture classroom. The responses of two (2) of the teachers A1 and C1 are represented in Table 4.27 above. However, another teacher H1 differs from the others by indicating that he experienced no change in students' retention ability after teaching them with the PBL strategy as compared to the traditional method (Table 4.27).

Finally, all eight teachers interviewed were of the view that the PBL strategy creates a positive attitude and interest in students and subsequently motivates students to learn on their own (Table 4.27). They indicated that the PBL strategy gives students the opportunity to discover things themselves. According to the sample teachers, students were curious and want people to recognize what they can do, and this motivated them to do more (Table 4.27). They added that the students break up in groups to research at their own pace (Table 4.27). These claims are consistent with the views of Surif et al., (2013) stating that motivation is enhanced once students realise that they are responsible for their own learning. Terry Barrett (2010) supported Surif et al., (2013) when he said that when students research and discover a solution to an ill-structured problem, it creates a positive attitude and motivates them to do more research. The remarks made by teacher A1, B2 and C1 are represented in Table 4.27 above.

Summary of teacher experiences using PBL

From the analysis, five (5) out of the eight (8) teachers interviewed measured a change in students' problem-solving skills and conclude that there was an improvement. Three (3) of them did not realise a change in students' problem-solving skills with the reason that they could not implement the program well.

On the other hand, all the sample teachers interviewed agreed that PBL has inculcated in students how to learn on their own. Furthermore, it was noted that one (1) of them

differ from other participants by indicating there was no change in students' retention ability. However, seven (7) out of the eight (8) teachers interviewed experienced a change in students' retention ability after teaching them with the PBL strategy. Finally, from the analysis above, all teachers agreed that the PBL strategy creates motivation and interest in students.

4.5.2 Successes during the implementation of the PBL strategy

This section reports the analysis of the information obtained on the successes during the implementation of the PBL strategy. Four questions were analysed (see Appendix E). Questions 2.1 and 2.2 were merged in section 4.5.2.1 because the questions are related. Also question 2.3 and 2.4 was merged in section 4.5.2.2 for the same reason

4.5.2.1 Teachers' feelings about the PBL teaching strategy and suggestions in the interest of improving it

Table 4.28: Responses of teachers to what they like or dislike about PBL and suggestion to improve what they dislike

Descriptions	Teacher's Excerpt	Frequency N=8
Like about PBL	B2: 'I like the PBL for the fact that the teacher does less, and the learners do more, and I dislike the strategy because is time consumption'. C1:' I like it for the fact that learners are actively involved but are difficult to organize especially writing an ill-structured problem and getting other teachers to support' E1: 'I enjoyed how we teamed up as colleagues in groups to solve problems and how we welcome each and everyone's idea during brainstorming'. D1: 'I suggest there should be an amendment in the timetable to give ample time for the PBL approach in the teaching of physics'	6

	F1: ‘Timetable should be extended; more resources need to be provided by management’ A1: ‘Department of basic education needs to change the curriculum to suit the PBL approach’.	
Dislike about PBL	G1: ‘I dislike PBL because is time-consuming. It needs learners who are motivated to learn. It requires a lot of effort to prepare an ill-structured question for learners’ H1: ‘I dislike the PBL approach since time was not enough for full implementation of the approach though is difficult to organize’	2

According to the analysis as depicted in Table 4.28, six out of the eight (8) teachers interviewed indicated they like the PBL strategy and gave various suggestions to improve it. Their claims are represented in Table 4.28. Teacher B2 indicated he likes the strategy because the teacher only acts as a facilitator but dislikes it because it is time-consuming (Table 4.28). The constructivist framework for learning supports the teacher as facilitating students’ learning in the process of constructing and reconstructing their own knowledge (Crawford, 2000, p. 918). Also, Surif et al., (2013) elaborates, the learner is at the centre of the teaching and learning process and the teacher's work is to facilitate and provoke learners’ learning. Similarly, other teachers indicated that they like the strategy because it actively involves students in the teaching and learning process but dislike it because it is difficult to organize a PBL lesson (Table 4.28). This claim has been affirmed by Tan (2003) in section 4.3.2 question 1, prior to the intervention.

From the analysis in Table 4.28, three views can be identified to correct what teachers dislike. Some suggested time to complete a lesson should be extended by the Department of Basic Education. Others said that the curriculum should be reformed to match with the PBL strategy. Teacher D1 suggested that timetable be amended by extending the period to make more time for PBL lessons. Researchers have affirmed that PBL is a research-based strategy where students could go out several hours to days to find a solution to an ill-structured problem and requires a huge amount of time

(Kolmos, 2017). The claims by teachers D1, F1 and A1 are indicated in Table 4.28 above.

On the contrary, two (2) out of the eight (8) teachers interviewed were of the view that PBL is time-consuming and they dislike it (Table 4.28). Kolmos (2017) supports the teachers' claim by stating that one of the disadvantages of PBL is that it is time-consuming. Kolmos (2017, p. 6) further stated that the timeframe in which to complete a PBL module is often too short to learn the added values of PBL. The comments by teachers G1 and H1 are represented in Table 4.28 above.

Summary of teachers' successes using PBL

In conclusion, the results show that although, according to the analysis, six (6) out of the eight (8) teachers interviewed indicated that they like the PBL strategy; they also expressed their dissatisfaction about the time constraints and difficulties in running a PBL lesson. On the other hand, it can be concluded that adopting a new teaching strategy that does not place much value on a standardized test and one short examination for promotion in South African schools will require a change in the curriculum since the South African school system operates on the end of year common examination to reward students to the next grade. The suggestion of teacher A1 is therefore important to ensure that the PBL program is implemented well at schools.

4.5.2.2 Teachers' preferences for the PBL strategy and their decisions to introduce the strategy to other colleagues

Table 4.29: Responses from teachers on their decision to continue the PBL or not and whether to introduce the strategy to other colleagues

Descriptions	Teacher's Excerpt	Frequency N=8
Continue with PBL	B2: 'I will like to continue using PBL because it has increase learner motivation to learn but on the other hand I dislike because is difficult to organize'. A1: 'I will like to have to continue using it because I could see it has enhanced learners problem-solving skills and it motivates them to learn when they are not forced to'. D1: 'Yes I will because learners enjoy the PBL strategy than the traditional method' F1: 'Yes I will recommend PBL to be used by other teachers because it has improved students' problem-solving skills and thinking ability'.	4
Discontinue with PBL	E1: 'I would discontinue implementing the PBL approach due to time constraints' G1: 'I will not recommend the PBL approach by other teachers because it cannot be fully implemented during regular lessons it is difficult and takes much time'. H1: 'I will not I don't think it can work in South African schools, learners will fail common papers'	4

Following the evidence from Table 4.29, four (4) out of the eight (8) teachers interviewed supported the continued use of the PBL strategy and promised to recommend to other colleagues for various reasons such as: it has helped to improve students' problem-solving skills, improve their critical thinking skills, creates fun, interest and motivation in students (Table 4.29). These claims are consistent with the

views of Terry Barrett (2010) when he stated that the PBL strategy provides an opportunity to use available resources and research for a solution to an ill-structured problem and turns to improve students' problem-solving skills and motivation. The comments made by the teachers are indicated in Table 4.29 above. On the contrary, four other teachers interviewed indicated that they will discontinue using the PBL strategy. These teachers decided not to introduce the PBL strategy to other colleagues in the district. Various reasons were stated; PBL is time-consuming; it is difficult to complete the ATP and it is difficult to plan a PBL lesson (Table 4.29). These claims are consistent with the views of Kolmos (2017) and Surif et al., (2013) (see section 4.5.2.1). According to the teachers, its implementation is not feasible in the South African school system (Table 4.29). The comments by teachers to discontinue the PBL strategy are represented in Table 4.29 above.

Summary of teachers' successes using PBL

In conclusion, it was noted from the analysis and comments made by participants that four (4)out of the eight (8) teachers interviewed may not want to continue using the PBL strategy to teach their physics learners with reasons that is time-consuming and difficult to organize. Furthermore, as per the South African school system, physics teachers are bound to complete their annual teaching plan at a time for learners to write a common provincial examination for promotion to the next grade. Students must be well-prepared for the common task based on the ATP and is difficult to complete the ATP if teachers are to go by the PBL strategy. This probably makes it difficult for teachers to implement the PBL strategy.

4.5.3 Challenges while implementing the PBL strategy

This section reports the analysis of the information obtained on the challenges' teachers were faced with during the implementation of the PBL strategy. Eight questions were analysed (see Appendix E). Questions 3.1, 3.5 and 3.6 were merged in section 4.5.3.1 during the analysis as the three questions were dealing with resource constraints and the responses from the respondents were almost overlapping. Also, questions 3.2, 3.3 and 3.4 were also merged in section 4.5.3.2 since they were all talking about time constraints.

4.5.3.1 Resource constraints, specific resource lacked or received and the extent of management support while implementing the PBL strategy

Table 4.30: Teachers' responses to resource constraints, specific resources lack or received and the extent of management support during the implementation of the PBL

Descriptions	Teacher's Excerpt	Frequency N=8
Availability of resources and management support	H2: 'There was enough resource provided by my school for the implementation of the PBL approach, money was made available by SGB to buy movable lab as it was in the school's plan already' A1: 'I appreciate management support management of my school were fully supportive of the implementation of the PBL approach as all lab equipment was provided and other teachers offer their lesson for PBL research and presentation to continue' G2: 'management support was minimal'	3
Lack of resources and management support	E1: 'No laboratory in the school, basic science kits and equipment were lacking, which affected outcome of the program'. 'management seems to have a negative attitude since other teachers were complaining about learners spending a lot of time in physics lessons' B2: 'We lack moral support from management, cooperation with other subject teachers were lacked, provision of basic resource was lacked' D1: 'no management support was noticed much was needed from management. laboratory equipment was not available, ammeter, voltmeter, and others'	5

	C1: ‘No there was no support from the school; management seems not to like the program because my principal complains when learners are out for research. No laboratory, there was no materials, students complain of basic things during research. No money to buy the required materials’ F1: ‘There was no ammeter and voltmeter at the school’	

As per the analysis reported in Table 4.30, five (5) out of the eight teachers interviewed said they lack various resources and management support for effective implementation and subsequently would affect students' learning outcomes (Table 4.30). They suggested that the lack of support may be due to the complaints by other teachers that physics students spend more time learning Physical Science than other subjects, which made PBL unpopular among management (Table 4.30). From the information gathered in Table 4.30, teachers indicated that they lack support such as moral support, cooperation from other teachers and basic resources such as laboratory equipment. On the other hand, the teachers also indicated that money to buy basic materials such as ammeter and voltmeter and the concern of management was lacking. They again stated that the principal and other teachers were not happy when students are out for research looking for information to answer the ill-structured problem (Table 4.30). Idiaghe (2004) performed a study that focused on the relationship between resource availability and effective teaching which results in academic productivity. Idiaghe (2004) noted that students in schools with inadequate teaching and learning materials perform poorly compared to their counterparts in a well-resourced school. The teachers’ claim was therefore consistent with the views of Idiaghe (2004).

On the contrary, the remaining three (3) other teachers differ from the rest by saying that management provided various materials required for the implementation and encourages students to take part in the research activity. Other subject teachers offer their lessons where necessary. Some said SGB gave them money to buy movable science kits, others said management provides money to buy circuit board, ammeter,

voltmeter etc. when they needed them (Table 4.30). Research has affirmed appropriate resources as pivotal to effective science teaching (Mudulia, 2012, p. 531). This therefore means that the program was implemented well in these schools

Summary of teachers' challenges pertaining to resources when implementing PBL

In conclusion, five (5)out of the eight (8) teachers interviewed indicated that management was not supportive, and various materials and equipment were lacking during the implementation of the PBL strategy. However, the remaining three (3)indicated they had various support from management and had the needed resources for the implementation of the strategy. It is obvious that teachers may not continue with PBL if even management are not in support of the program.

4.5.3.2 Time constraints in relation to time allocated in the Curriculum Assessment and Policy Statement (CAPS) Physical Science documents, time to complete a PBL lesson and reasons for teachers not completing ATP if they are to continue with the PBL strategy

Table 4.31: Teachers' responses to time constraints in using the PBL strategy

Descriptions	Teacher's Excerpt	Frequency N=8
Time to complete a PBL lesson in relation to time allocation in the Curriculum Assessment and Policy Statement (CAPS) Physical Science document per lesson	A1: 'The PBL uses a lot of instructional hours as compare to what is in the CAPS document' B2: 'PBL needs more time since learners will have to go out and research on the topic before they present their solution' F1: 'Time allocated in the CAPS document is not enough for the implementation of the PBL strategy'	8

Teachers reasons not to finish a PBL lesson in 1 hour	E1: ‘I was not able to finish in one hour because of the research stage learners needed more time to do that’ C1: ‘I could not finish the PBL lesson in an hour because it requires a lot of time for learners to research and presents their work’ H1: ‘I couldn't finish because learners need time to go out and research and get information to answer the ill-structured problem’	7
	G1: ‘Because the PBL approach require learners to go and investigate the problem which is time-consuming, and learners were struggling to follow the processes of PBL’	1
Teachers reasons not to complete ATP	C1: ‘I won't be able to finish because the PBL lesson/approach requires a lot of instructional hours’ H2: ‘With the continued implementation of the PBL approach, I would not be able to complete the annual teaching plan since it is time-consuming’	5
	B2: ‘students spend much time during research looking for information, they need a lot of time to finish their work’ C1: ‘a lot of time is wasted by students, during the PBL lesson and this will affect time to complete ATP’	3

Some of the major challenges’ teachers are faced with when applying PBL, is time. All the teachers interviewed indicated that the PBL strategy uses a large amount of instructional hours compared to the time allocated per lesson in the Curriculum

Assessment and Policy Statement (CAPS) Physical Science document (Table 4.31). They indicated that PBL requires a lot of time since learners will have to go out and do research (Table 4.31). The responses of teacher A1, B2 and F1 are represented in Table 4.31. Kolmos (2017, p. 6) supported the teachers' claim by indicating that the time frame for completing a PBL module is often too short since students would have to do research to enable them to answer the driving question.

When the teachers were asked the reason why they were not able to finish their lessons in 1 hour, all the sample teachers cited almost the same reason, namely that the PBL strategy requires a large amount of time. This confirmed the claim by teachers in section 4.5.2.1 and 4.5.2.2 and was consistent with the views of Kolmos (2017) and Surif et al., (2013). The comments by teachers E1, C1 and H1 are represented in Table 4.31. However, teacher G1 differs in his reason by adding that even though he could not finish in 1 hour due to the time constraint, students were also complaining that it is difficult to follow the processes of the PBL (Table 4.31).

Moreover, when teachers were asked to give reasons why they cannot complete their ATP if they continue applying the PBL strategy, various reasons were given. Five (5) out of the eight (8) teachers interviewed said they cannot complete their ATP with reason that PBL requires a lot of time to finish a lesson (Table 4.31). Three other teachers from the sample space said they cannot complete because the student needs a lot of time during research (Table 4.31). These claims again are confirmed by Kolmos (2017) and Surif et al., (2013) and the analysis in section 4.5.2.1 and 4.5.2.2.

Summary of teachers' challenges pertaining to time when applying PBL

In conclusion, all the sample teachers indicated that the PBL strategy uses a large amount of time as compared to time allocated in the Curriculum Assessment and Policy Statement (CAPS) Physical Science document. As a result, it is a challenge to run a PBL program in the South African high school system based on the evidence gathered. In section 4.5.2 question 2.1 teachers said they dislike PBL because it is time-consuming. In question 2.2 of section 4.5.2, teachers said they will not continue to use the PBL because it is time-consuming. In the same question 2.2, teachers indicated they would not introduce PBL to other colleagues because it is time-

consuming. This is evidence that the major disadvantage in using the PBL strategy is time (Kolmos, 2017).

Furthermore, it can be concluded that even though one (1) the interviewed teachers indicated that students were struggling to follow the PBL process, in general, it was noted from the analysis that seven (7) out of the eight (8) teachers interviewed were struggling to use the PBL strategy due to time constraint. This confirms the previous analysis in section 4.5.2 questions 2.1 and 2.2 that the PBL strategy uses a large amount of instructional hours.

Finally, from the analysis that five (5) out of the eight (8) teachers generally said they cannot complete their ATP due to time. Three (3) others indicated that students need a lot of time during research and this could affect time to complete ATP. In general, one of the stumbling blocks in using the PBL strategy in the South African educational system is time.

4.5.3.3 Specific problems teachers encountered while implementing the PBL strategy in their physics classroom?

Table 4.32: Teachers' responses to difficulties encountered during implementation.

Descriptions	Teacher's Excerpt	Frequency N=8
Students' readiness to work	A1: 'sometimes learners do not want to work, and I have to follow them to get them to work'	1
Time constraint	B2: 'I realised time was a problem and sometimes I have to ask for my colleagues' period'	3
Cooperation from other teachers	G2: 'in most cases it is difficult to get the cooperation of other subject teachers, they either feel you given them more work or you want to test them'	2

lack of information during research	E1: ‘sometimes learners complain of information from other subject teachers, they always give excuses and end up disappointing’ H2: in some cases, learners complain they are not getting sufficient information to answer the driving question’	2

When teachers were interviewed on the difficulties, they encountered during implementation of the PBL strategy, various answers were given. Some of them are; students’ preparedness, time constraint, lack of enough information during the research, difficulties in getting other subject teachers to cooperate and lack of proper communication between subject teachers, which often results in students occasionally getting stacked with information during research.

The participating teachers indicated that students were often not prepared, and the teacher must chase them to get on with their work (Table 4.32). This is often the case when students are left alone to do their own work. While some may feel engaged and busy with their work, others may feel disengaged. This claim is consistent with the views of Kolmos (2017) who said that reasons why students may not concentrate could be lack of maturity to engage in group activities, being unfamiliar with open-ended problems and lack of prerequisite knowledge. Again, Kolmos (2017) further emphasized that another reason why students may not want to work on PBL projects is that they feel they have been given an extra workload as they get much more involved and engaged in the learning than other students.

Furthermore, three other teachers indicated that time was a problem and that they occasionally have to ask for other teachers' lessons (Table 4.32). This claim was consistent with the views of Kolmos (2017) in question 3.2 of this section.

In another development, two other teachers indicated that students used to complain they were not receiving enough information during the research stage (Table 4.32). This problem could be associated with lack of support from subject teachers. Again, Kolmos (2017) supported this claim by indicating that lack of communication among

subject teachers to support the PBL program remains a major challenge in sustaining the PBL strategy in schools.

Finally, two teachers indicated that students often complain about information from other subject teachers which often get them stacked during research (Table 4.32). Researchers have proven that, in a PBL lesson, students are expected to be supported by other subject teachers to gather information to answer the driving question and/or the ill-structured problem (Kolmos, 2017).

Summary of difficulties teachers faced using the PBL

In conclusion, one (1) out of the eight (8) teachers interviewed complained about students' readiness to work which could probably be attributed to difficulties in following the PBL process. Three (3) said time to complete the PBL lesson is a problem. Two (2) complained about the reluctance of subject teachers to actively involve themselves in the program. Finally, two (2) indicated that students complain about lack of information during research.

4.5.3.4. Benefits students derived when taught with the PBL strategy

Table 4.33: Teachers' responses to the benefits of applying the PBL strategy

Descriptions	**Teacher's Excerpt**	Frequency N=8
Problem-solving skills	A1: 'the PBL strategy gives longer retention ability, improve problem-solving skills, increase motivation and create fun for learners while learning'	3
Critical thinking and self-directed learning	B2: 'If well implemented and supported; PBL will increase learners' interest and learners' competencies to higher physics education as well as improving learners thinking ability and self-directed learning'	2

Collaboration and presentation skills	G2: ‘the PBL approach improves learner's knowledge in searching for information when they are doing research, improves learner's communication and presentation skills when they showcase their work’ E1: ‘It enhances learners interpersonal and communication skills’	3

Various advantages were mentioned when teachers were asked to name the benefits of PBL from their own experience. According to the analysis, three (3) out of the eight (8) teachers interviewed realised that the PBL strategy enhances students’ thinking skills, improves problem-solving skills, gives longer retention ability and increases the student's motivation to learn physics (Table 4.33). This claim is consistent with the views of De Graaff and Kolmos (2003) when they stated that the PBL education strategy can solve problems during the learning process.

Furthermore, two (2) out of the eight (8) teachers interviewed mentioned that the strategy improves students' thinking ability and self-directed learning and enhances learners' competencies to higher physics education (Table 4.33). In a research conducted by Norbaizura (2006) the results show that respondents agreed that one of the benefits of PBL is that it enhances self-directed learning skills in students. The findings of Norbaizura (2006) were consistent with the views of Nafis (1999) who had a similar result that PBL promotes independent learning in students. Nafis (1999) and Norbaizura’s (2006) findings cited in Surif et al., (2013) therefore support the teachers’ claim.

In another development, three (3) out of the eight (8) teachers interviewed teachers indicated that the PBL strategy enhances learners' skills in communication (Table 4.33). Barrows and Tamblyn (1980) supported this claim when they said that good communication and interaction between groups is the most important factor that influences learning in students in a PBL classroom.

Summary of the benefit of using PBL

In general, teachers have experienced the PBL strategy and have witnessed that it has a number of benefits as opposed to the traditional instructional strategy. Nevertheless, the opinions, comments, and suggestions of the teachers as represented in this study were based on the experiences of using the PBL strategy. Hence the researcher suggests in his next study to study the impact of PBL on students' academic performances where a pre-test and a post-test will be organized to assess a change in students' academic performances. Even though the PBL strategy has been witnessed to have a large number of positives, approximately ten (10) teachers may not continue to use the strategy with reasons discussed in section 4.5.1 question 1.2.

4.6 SUMMARY

This chapter focused on the results from the analysis of the data from the participants (teachers) in the selected schools. The quantitative and qualitative data collected using the two questionnaires (Q1BI and Q2AI) were presented, analysed, interpreted and supported by the literature. The Reform Teaching Observation Protocol (RTOP) was used to capture what happened in the classroom before and after the intervention. This was analysed, interpreted and supported by evidence from the literature. In addition, a semi-structured interview was used to determine the opinions and views of respondents concerning their experiences of the use of the PBL strategy. They reflected on their successes and challenges during the implementation of the strategy. The questionnaire, the lesson observation, and the interview questions were designed to answer the three sub-questions that were developed, namely:

1. What are the teachers' experiences when implementing PBL, prior to an intervention?
2. How do these physics teachers implement PBL in their classrooms?
3. What are the successes and challenges of these physics teachers when applying PBL in their classrooms?

The results make it clear that, the Physical Science teachers at the Entriken cluster were basically between the ages of 25 and 35 years. Even though they had a strong academic background, they may be inexperienced since they have less number of

years in teaching physics at the FET. The majority of the teachers' (seven out of sixteen) teaching experience was between 0 and 5 years. Furthermore, from the analysis of the Q1BI section B, teachers had no knowledge of and skills pertaining to PBL prior to the intervention. However, the analysis of Q2A1 indicated that teachers had enough knowledge of PBL after the intervention to be able to implement the strategy in their classrooms.

In addition, lesson observations were done by using the Reform Teaching Observation Protocol (RTOP). Prior to the observation, teachers claimed to use various active teaching methods such as the problem-solving method, demonstration method, discussion method, question and answer method and the inquiry-based method (section 4.3.1). However, during the observation before the application of intervention, teachers were observed using the teacher-centred strategy to teach physics. These teachers plan their lessons without considering students' prior knowledge. Students were not actively involved in the lesson, no students' exploration was observed, students were not encouraged to engage in constructive criticism and students' comments and ideas were not used to determine the directions of the class discussions (see sections 4.4.1 to 4.4.5). However, after the intervention and during the implementation of the PBL strategy, teachers improved on all the skills in these criteria and students were motivated (see sections 4.4.1 to 4.4.5).

The results obtained from the interview schedule revealed that teachers were generally motivated regarding the PBL strategy because it has enhanced students problem-solving skills, improved their critical thinking skills and has instilled in them self-directed learning and motivation (see section 4.5.1.2). On the other hand, though, teachers complained that it was difficult to organize a PBL class and that it is time-consuming (see section 4.5.3.2). They therefore decided not to recommend the strategy to other colleagues in other districts because the teachers would not be able to complete their annual teaching plan (ATP) if they were to implement the PBL strategy.

CHAPTER FIVE
SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter presents the summary of the findings with regard to the problem statement, research questions, aims, and objectives of the research (see sections 1.4, 1.5 and 1.6). The conclusions were based on the findings from the study (see section 5.2). Recommendations for improving the teaching and learning of physics in high schools using the PBL strategy is discussed (see section 5.4).

The study was meant to discover the experiences of physics teachers when implementing problem-based learning (PBL) in their physics classrooms. Hence the following research questions directed the study:

What are the experiences of physics teachers when implementing Problem-Based Learning (PBL) ***in their classrooms?***

Three sub-questions were developed, namely:

1. What are physics teachers' experiences when implementing PBL, prior to an intervention?
2. How do these physics teachers implement PBL in their classrooms?
3. What are the successes and challenges of these physics teachers when applying PBL in their classrooms?

5.2 SUMMARY OF FINDINGS

In answering the three (3) research questions, data were collected using three research instruments; namely the Q1BI and the Q2AI, the Reform Teaching Observation Protocol (RTOP) and a semi-structured interview. The data collected from these instruments were analysed quantitatively using statistical representation and qualitatively using thematic analysis techniques. The findings have been

summarized under the following subheadings to assist in answering the research questions:

1. Teachers' knowledge of PBL before and after the intervention to answer research sub-question 1
2. Lesson observation before and after the intervention to answer research sub-question 2
3. Successes and challenges of PBL during implementation to answer research sub-question 3

5.2.1 Teachers' knowledge of PBL before and after intervention

Research sub-question 1

What are physics teachers' experiences of the use of PBL before an intervention?

The results of the analysis show that teachers had limited knowledge and skills in the use of the PBL strategy before the intervention (see section 4.3 2). Evidence from the analysis indicates that twelve (12) out of sixteen (16) teachers could not define the concept *problem-based learning*, fifteen (15)out of sixteen (16) could not describe the processes of PBL and all the participating teachers could not demonstrate knowledge of the requirement of a problem (how to formulate a problem) when applying the PBL strategy (see section 4.3.2). Furthermore, thirteen (13) out of sixteen (16) teachers presented lessons that were teacher-centred (traditional instructional strategy) (see section 4.3.2). Moreover, thirteen (13) out of sixteen (16) teachers could not demonstrate knowledge of how to assess students' understanding (see section 4.3.2). Even though fourteen (14) out of sixteen (16) demonstrated knowledge of the objectives of developing physics lesson but in general, teachers did not demonstrate much knowledge of and skills in the use of the PBL strategy prior to intervention (see section 4.3.2).

However, after the four-weekend intervention workshop to equip teachers with the required knowledge of and skills in PBL, the Q2AI which consisted of the same items as Q1BI section B was administered to measure the level of knowledge acquired on

PBL. As clarified through the analysis, all the participating teachers demonstrated knowledge and skills in the use of the PBL strategy. In section 4.3.2 it was indicated that fifteen (15) teachers could define problem-based learning (PBL) correctly compared to four (4) before the intervention. Furthermore, fourteen (14) could describe the processes of PBL compared to one (1) before the intervention; fourteen (14) demonstrated knowledge of the requirement of a problem as opposed to no teacher before the intervention. Again, a further fourteen (14) presented a lesson that was learner-centred after intervention compare to one (1) before intervention and did not consider students' RPK. Finally, all the teachers demonstrated knowledge of how to assess students' understanding after intervention compared to three (3) before the intervention.

When teachers were afforded the opportunity of reflecting on the PBL strategy, fourteen (14) teachers expressed positive attitudes towards the intervention program, which could mean that they appreciate the knowledge they obtained during the intervention (see section 4.3.3). Then again, thirteen (13) teachers prefer to use the PBL strategy to teach their physics students (see section 4.3.3).

When teachers were interviewed after the implementation to find out more about their experience in using the PBL strategy, ten (10) teachers realised a positive change in their students' problem-solving skills after teaching them with the PBL strategy (see section 4.5.1 question 1.2). On the other hand, all the interviewed teachers agreed that the PBL strategy inculcates in students how to learn on their own (see section 4.5.1 question 1.2).Furthermore, all the participating teachers were of the view that from their experience the PBL strategy creates motivation and interest in students to learn physics (see section 4.5.1 question 1.2). In another interview, fourteen (14) teachers said they experienced a change in students' retention ability after teaching them with the PBL strategy (see section 4.5.1 question 1.2). These findings can be observed under the constructivist lens such that according to Hung (2011) and Kumar (2010) the essential features of PBL that reflect constructivism are that: self-directed learning occurs within a social context, the focal point of learning is the acquisition of conceptual understanding, problem-solving skills, critical thinking skills, and collaborative setting.

However, after all the positives attached to the PBL strategy experienced by the teachers, the evidence gathered in section 4.5.1 question 1.1 indicated that it is likely that most teachers at Entsikeni cluster may not continue to use the PBL strategy. The reason is that ten (10) of these teachers indicated that it is inappropriate to use because it is time-consuming, difficult to complete ATP and difficult to develop an ill-structured problem. This study agrees with other researchers where they found that time is a problem when new teaching strategies are experimented on (Kolmos, 2017, p. 6; Snavely, 2004). Other researchers also found that it is difficult to complete ATP (Kolmos, 2017, p. 6; DeWitt, Alias, Siraj, & Spector, 2017). The study also confirms findings from other studies that it is difficult to develop ill-structured problems (Hung, 2011; DeWitt, Alias, Siraj, & Spector, 2017).

5.2.2 Lesson observations before and after intervention

Research sub-question 2:

How do these physics teachers implement PBL in their classrooms?

Evidence from section 4.3.2 shows that physics teachers at the Enteikeni cluster had limited knowledge of the PBL strategy and therefore needed an intervention before implementing the strategy in their physics classrooms and assesses the successes and challenges. In this light, the teachers were given a four-weekend intervention workshop on the PBL strategy to equip them with the required knowledge of and skills in PBL to implement it during the teaching of their physics students.

The analysis of the result revealed that the teachers had enough knowledge of the use of the PBL strategy after the intervention had been applied (see section 4.3.2).

Consequently, teachers implemented the strategy in their classrooms to gain first-hand experience in using the strategy. The duration of implementation was two weeks. Before the implementation, lessons were observed to verify teachers' teaching practices. During the implementation, stage lessons were again observed to determine how the teachers used the PBL strategy in their classrooms compared to their teaching strategy before the implementation. This was done to assess whether a change could

be noticed in the teachers' teaching practices. The data collected during the observation schedule before and after intervention were presented, analysed, interpreted and supported with evidence from literature (section 4.4).

The analysis from section 4.3.1 has made it clear that when teachers were asked about their preferred teaching strategy with reasons, thirteen (13) of the teachers indicated that they prefer the following active teaching strategies; problem-solving, demonstration, discussions, inquiry-based, question-and-answer method and only three (3) indicated that they preferred the traditional lecture instructional strategy. However, when teachers were observed in their classrooms prior to intervention, the data collected indicated that all the teachers were using the traditional lecture instructional strategy (section 4.4.1). This means that teachers' preferred teaching strategies were not used during the classroom observation. This could probably mean that although they prefer the active teaching methods, they are not comfortable in using them in their class. The evidence recorded during the lesson observation prior to intervention is represented in section 4.4.6.

During the physics teachers' implementation of the PBL strategy after the intervention workshop, it was found from the analysis of the RTOP that there was an improvement in teachers' lesson delivery (see section 4.4.6). The results suggested that there was an improvement in their knowledge of planning and implementing an active PBL lesson. This could be because the teachers were afforded an opportunity of experiencing the PBL strategy first-hand.

Although there is no universally accepted method of teaching, the constructivists have indicated that knowledge is not transmitted directly from a teacher to a student but is a result from students constructing their own understanding (Gautam, 2018). This therefore suggests that the 'ideal' method of teaching is one that actively involves students in the teaching and learning processes so that the students build up their own knowledge. This links up with the constructivist view that the teacher must act as a facilitator, ensure that the teaching method used enhances the scientific way of thinking, actively involves students, develops problem-solving skills and creates interest and motivation (Gautam, 2018). One of such teaching strategies is problem-based learning (PBL) (Tan, 2003; Goodman, 2010; Karaçalli & Korur, 2014). As a

result, there is the need for continuous professional development interventions to introduce physics teachers to this alternative teaching strategy that increases students' engagement and can assist them in developing the 21st-century skills, for example problem-solving skills, critical thinking skills, and collaborative skills.

5.2.3 Successes and challenges of PBL during implementation

Research sub-question 3

What are the successes and challenges of these teachers when implementing PBL in their classrooms?

Results from the analysis of Q1BI, Q2AI and RTOP, and the interview protocol suggest that in general, the PBL program witnesses some successes as can be seen from teachers' experiences. According to the teachers and from the analysis, the PBL strategy has developed in students the added values of PBL as discussed earlier in section 5.2.1 in this chapter. However, this was as a result of the effective implementation of the PBL strategy in the teachers' respective schools (see section 4.4). Teachers' teaching practices improved after they were observed with the RTOP before and after the intervention program as discussed in section 5.2.2 in this chapter.

Despite the successes, teachers were faced with some challenges during the implementation of the PBL strategy. The core of these challenges is time. According to the analysis, six (6) out of the eight (8) teachers interviewed indicated that they like the PBL strategy but also expressed their dissatisfaction about the time constraints and difficulties in running a PBL lesson (see section 4.5.2 question 2.1). On the other hand, four (4) of the teachers said they would not continue using the PBL strategy to teach their physics students with reasons that it is time-consuming and difficult to organize (see 4.5.2 question 2.2).

Similarly, all the participating teachers complained that PBL uses more time compare to time allocated in the Curriculum Assessment and Policy Statement (CAPS) Physical Science document. As a result, it is a challenge to run a PBL program in the South African high school system (see section 4.5.3 question 3.2). Furthermore, it was noted from the analysis in section 4.5.3 question 3.2 that seven (7) teachers were struggling

to use the PBL strategy due to the time constraint. This confirms the previous analysis in section 4.5.2 questions 2.1and 2.2 that the PBL strategy uses a lot of instructional hours compared to the traditional instructional strategy. When teachers were asked whether they would be able to finish their ATP as scheduled if they were to continue with the PBL strategy, five (5) said they cannot complete due to time. In addition, three (3) of the teachers indicated that students need more time during research and this could affect time to complete ATP (see section 4.5.3 question 3.2). This is evidence that the major disadvantage in using the PBL strategy is time (Kolmos, 2017).

Other constraints in the use of the PBL strategy as experienced by the teachers are lack of materials. According to the analysis, five (5) teachers lack various materials required during implementation, which could possibly affect proper implementation of the program in those schools (see section 4.5.3 question 3.1). This is evident when five (5) teachers complained that management was not supportive and various materials and equipment were lacking during the implementation of the PBL strategy (see section 4.5.3 question 3.1).

Moreover, another major challenge in the implementation of the strategy is the lack of information during research. According to the analysis in section 4.5.3 question 3.3, two (2) teachers indicated that students complain about the lack of information during research.

Furthermore, students do complain during a PBL lesson that they have been given extra work. This occasionally makes them feel reluctant to work. Students' readiness to work is another challenge when using the PBL strategy. According to the analysis, one (1) teacher complained about students' readiness to work, which could probably be attributed to difficulties in following the PBL process (section 4.5.3 question 3.3). Finally, another constraint that was identified during the analysis is cooperation with other subject teachers. As per the analysis in section 4.5.3 question 3.3, two (2) teachers complained about cooperation with other subject teachers to support the PBL program. Consequently, this affects students' research during a PBL lesson.

In general, teachers had experienced the PBL strategy and have witnessed it to have more benefits as opposed to the traditional instructional strategy. Nevertheless, the

opinions, comments, and suggestions of the teachers as represented in this study were based on their experiences of using the PBL strategy. According to Moussaïd, Kämmer, Analytis and Neth (2013) opinion drive a person's behaviour.

5.3 CONCLUSIONS

In conclusion, the following needs to be highlighted. The teachers teaching physics at the Entsikeni cluster are professionally and academically qualified, but may be inexperienced in teaching physics in the FET and could probably affect students' academic performance (section 4.2.4 and section 4.2.5). Secondly, it was also found that although three (3) teachers were academically and professionally qualified to teach in high schools, they lack the content base to teach physics. This may probably also account for the poor performance in Physical Science in the district (section 4.2.4 and section 4.2.5).

Rice (2013) explained that experience promotes effectiveness, and if physics teachers are experienced, they are more likely to use inquiry and inquiry-based teaching which is ideal for science teaching (Tseng et al., 2013). However, researchers have proven that if inexperienced trained teachers apply active learning strategy, they tend to increase students' attendance, higher students' engagement and subsequently improve students' performance as compared to using the traditional instructional method (Deslauriers, Schelew & Wieman, 2011). Following the argument above, it is expected that since the teachers are academically and professionally qualified if, in addition, they adopt the PBL teaching strategy, they will stand a better chance of improving students' academic performances in Physical Science in the district.

Evidence gathered from the study indicates that it is likely that the teachers at Entsikeni cluster may not continue to use the PBL strategy since most of the teachers indicated that it is inappropriate to use the PBL because it is time-consuming, difficult to complete ATP and to develop an ill-structured problem. Among other factors such as difficulties in creating and implementing a PBL task that hinder the adoption of PBL strategy in schools, a curriculum change is also required to adopt this new teaching strategy that does not place much value on a standardized test and one short examination for promotion. The South African school system operates on the end of

year common examination to reward students to the next grade and need a curriculum restructuring to adopt a new teaching strategy (PBL) that reflect the constructivist approach which suggests that the teacher changes from being the store of information to students to becoming a facilitator, as students construct and reconstruct their own understanding through collaboration and problem-solving (Akçay, 2009).

5.4 RECOMMENDATIONS

The following recommendations are made to influence physics teachers in the use of problem-based learning (PBL) strategy to enhance students' engagement and subsequently improve students' performances, interest and motivation to study physics.

1. Promoting healthier and creative learning environments for PBL

A teaching and learning environment that is likely to actively engage students, enhances the creation of flexible knowledge, and promotes cooperation and independent inquiry-based learning is recommended for problem-based learning. Teachers must help in the formation of social groups among students that promote learning by exploiting their desire to be with their friends. School management and the department of education should help resource schools with laboratory and laboratory equipment, science textbooks and other equipment that will make the schools science-friendly. Computers, internet facilities, and Wi-Fi need to be provided to help students during research and to make them digitally literate.

The OBE failed because of the many challenges faced which include lack of educational materials, inadequate financial and human resources. However, this could also possibly influence the failure of PBL because during the interview, teachers said they could not implement the PBL successfully due to inadequate resources. Research has proven that the two basic requirements for successful implementation of a PBL curriculum are small class sizes and sufficient economic resources to make materials accessible for exploitation by both students and teachers (Carrera, Tellez & D'Ottavio, 2003). In fact, a popular argument against PBL is that it is costly in terms of money, time and space. This however makes it difficult for one to trust a successful

implementation of PBL in a developing country like South Africa where large class sizes and inadequate supply of educational materials remains an issue. Provision of educational resources is therefore paramount to implementation of a new system (PBL) that is based on learning by doing.

2. Professional development intervention programs for high school physics teachers on the use of the PBL strategy

There is the need for professional development of physics teachers in the Harry Gwala district by the department of education. The aim of this is to develop their understanding of the use of the PBL strategy and to adapt to teaching their physics students since the strategy could enhance student engagement and improve performance. Stakeholders should institute teacher education programs to periodically prepare high school physics teachers for the use of the PBL strategy. The suggestion is important in order to address some of the challenges which aggravated the failure of the OBE system which was introduced in 1997 with almost similar objectives as PBL. In a PBL lesson, the teacher acts as a facilitator provoking student learning. The teacher can be an effective facilitator stimulating students to learn if they understand how students learn. Professional development interventions such as PBL must also include activities that foster growth in teachers' understanding of how adolescents learn.

3. The need for a curriculum reform to incorporate the PBL strategy

During the interview, teachers were of the view that the PBL strategy is time-consuming and therefore makes it difficult to complete a PBL lesson in one hour. The researcher recommends that curriculum reforms need to be considered to accommodate the PBL strategy in such areas as assessments, syllabus coverage and timetabling since the PBL strategy has been confirmed to be a suitable strategy for teaching physics. The researcher is again of the view that the curriculum change should firstly be explored introducing a pilot project from the sub-district level, district level, provincial level to national to avoid a national failure as in the OBE system.

4. Impact of PBL on physics students' learning

This level was not assessed by this study, but I hope to assess it in my next study where students' understanding will be measured before and after the PBL strategy is implemented.

5. Introduction of PBL teaching strategy at Entsikeni cluster

Teachers at Entsikeni were inexperienced in teaching physics in the FET and could probably affect students' academic performance. Although they have degrees, three (3) are not fit to teach physics. If these findings could be generated to the rest of the district, it could be that if there are more teachers without teaching experience it could probably mean high ineffectiveness and could subsequently lead to poor physics performance in the district. Hence there is the need to introduce the problem-based teaching strategy. Research has affirmed that once they are inexperienced if they adapt the PBL teaching strategy, it is likely to increase students' attendance, higher student engagement and subsequently improve students' performances compared to when they use the traditional instructional method (Deslauriers, Schelew, & Wieman, 2011).

5.5 SUGGESTIONS FOR FUTURE STUDIES

This study was conducted at Entsikeni in the Harry Gwala district KwaZulu-Natal, South Africa. The study was directed to only eight (8) high schools and information was collected from physics teachers on their perceptions and opinions about their experience when they applied the PBL strategy to teach physics in their schools. Further studies could probably be performed in other schools in the Harry Gwala district and in other districts in KwaZulu-Natal as well as in the other eight provinces in South Africa to get a vivid picture of the experiences of physics teachers when implementing problem-based learning (PBL) in their classrooms.

The impact of problem-based learning (PBL) on students' competencies is one area that also needs more research. Researchers need to disseminate their findings by publishing articles on the extent to which PBL improves students' academic

performances so that stakeholders, education departments, curriculum developers, teachers as well as students would appreciate and adopt the PBL strategy for teaching and learning. Research has confirmed that the PBL strategy is a better option than the traditional lecture method in terms of developing students' problem-solving skills, improving critical thinking skills, longer retention ability, enhancing collaboration and developing interest and motivation in students to learn physics.

The researcher agrees that completing the classroom observation sheet involve inference and personal bias and this could possibly compromise the validity of the study. However, this study took place in a rural part of the country and a suitable trained observer was not available. The researcher has therefore suggested using trained observers as independent evaluators so that description given during data collection and analysis could substantiate judgments. Furthermore, the researcher agrees that questionnaire have limited validity especially when it is used in an environment where agreement is valued. This could be a reason why there was a mismatch between the teachers' response and what was observed in class. More attention would be paid to validity issues in a future study.

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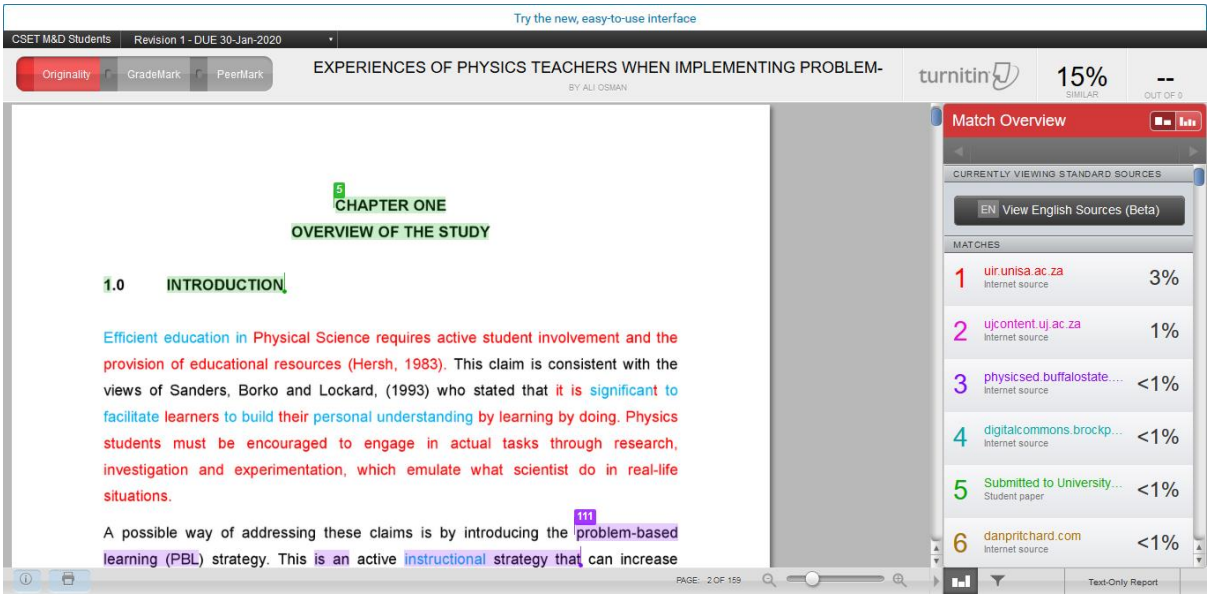
APPENDIX A

TURN IT IN FINAL REPORT



APPENDIX B

PROFESSIONAL LANGUAGE EDITORS CERTIFICATE

24 December 2018

I, **Ms Cecilia van der Walt**, hereby declare that I took care of the **editing** of the **dissertation** of **Mr Ali Osman** titled ***Experiences of Physics Teachers when Implementing Problem-Based Learning.***

MS CECILIA VAN DER WALT

BA (*Cum Laude*)
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APPENDIX C

QUESTIONNAIRE FOR PHYSICAL SCIENCE TEACHERS

QUESTIONNAIRE BEFORE PROFESSIONAL DEVELOPMENT INTERVENTION WORKSHOP

PART 1

Teacher's initial knowledge and skills in PBL before professional development intervention *workshop*

INSTRUCTIONS:

Please carefully read the following and fill the spaces provided. Tick the box with **[x]** where necessary in where necessary and give written answers where spaces are provided.

SECTION A: Background Information of respondents:

1. Name of school (optional) .....
2. **Please kindly indicate your school type**

MST SCHOOL	Urban	1
MST SCHOOL	Rural	2
NON-MST SCHOOL	Urban	3
NON-MST SCHOOL	Rural	4

3. **Please indicate your gender**

Male	1
Female	2

4. **Please indicate your age group**

YEAR GROUP	
20 – 25 Years	1
25 – 30 Years	2
30 – 35 Years	3
35 – 40 Years	4
40 – 45 Years	5
45 – 50 Years	6

5. **Please indicate your teaching experience in Physical Science**

YEARS	
0 – 5 Years	1
5 – 10 Years	2
10 – 15 Years	3
15 – 20 Years	4

20 – 25 Years	5
25years and above	6

6. **Please indicate your highest academic qualifications**:

ACADEMIC QUALIFICATION	
Natural science grade 9	1
Physical Science grade 12	2
Bachelor of Education Degree (BED)	3
Bachelor of science degree (BSc)	4
Honours Bachelor of Education degree	5
Honours Bachelor of Science degree	6
Master of Education degree	7
Master of Science degree	8
Doctor of philosophy	9
Doctor of Education degree	10
Others (please specify) ……	11

7. Please indicate your **highest professional qualifications**:

PROFESSIONAL QUALIFICATION	
Teacher's certificate	1
Diploma in Education	2
Advanced Certificate in Education (ACE)	3
Postgraduate certificate in education (PGCE)	4
Postgraduate diploma (Higher Education Diploma)	5
Others (please specify) ……....	6

8. What was your major subject(s) during your training as teacher?

Physics only	1
Chemistry only	2
Mathematics only	3
Physics and Mathematics	4
Physics and chemistry	5
Physics, chemistry and mathematics	6
Chemistry and life sciences	7
Others.....	8

SECTION B:

INSTRUCTIONS: Please, mark with an **X** for the right answer in question 9 and provide written answers for the rest of the questions.

1. What teaching strategy do you prefer when teaching physics lessons? Explain why you prefer this teaching strategy.

_____
_____

2. Provide a definition for problem-based learning (PBL) from your perspective.

_____
_____

3. Provide a definition for project-based learning from your perspective.

_____
_____

4. Describe the processes of problem-based learning (PBL) from your perspective

_____
_____

5. What do you think are the requirements for a problem when you use the problem-based learning (PBL) approach?

_____
_____

6. Describe how you will present the following content in your class

Grade 10
Term 2
Topic: the impact of electrical energy on the over growing industry
Content: current electricity

_____
_____

7. What do you want your learners to learn when developing this lesson?

_____
_____

8. How would you know your learners understand the topic?

_____
_____

APPENDIX D

QUESTIONNAIRE AFTER PROFESSIONAL DEVELOPMENT INTERVENTION WORKSHOP

PART 2:

Teachers experience in PBL after professional development intervention workshop

INSTRUCTIONS:

Please carefully read the following and fill the spaces provided. Tick the box with **[X]** where necessary and complete statements where spaces are provided.

1. Briefly explain what you liked or disliked in the workshop?

_____

_____

2. Provide a definition for problem-based learning (PBL) from your perspective after the workshop

_____

_____

3. Describe the process of problem-based learning (PBL) from your perspective after the workshop

_____

_____

4. What do you think are the requirements for a problem when you use the problem-based learning (PBL) approach, after the workshop?

_____

_____

5. Will you use the PBL approach in your classroom? If yes, why and if no why not.

_____

_____

6. Describe how you will present the following content in your class

Grade 10

Term 2

Topic: the impact of electrical energy on the over growing industry

Content: current electricity

_____

7. What do you want your learners to learn when developing the lesson?

_____

_____

8. How would you know your learners understand the topic?

_____

_____

APPENDIX E
INTERVIEW PROTOCOL WITH TEACHERS

PART 3: Semi-structured interview

INSTRUCTIONS:

Please carefully answer the following questions verbally precisely as possible

1. Experiences of teachers before and after implementation of the PBL strategy

1.1 How do you understand problem-based learning?

1.2 In your opinion, why do you think it is appropriate or inappropriate for physics to be taught and studied using the PBL approach?

1.3 How would you compare learner problem-solving skills before teaching them with the PBL strategy and after teaching them with the PBL strategy?

1.4 After using the PBL approach in teaching and learning physics for some time, do you agree or disagree that PBL improves problem-solving skills in learners?

If yes, please give reason_____

If no, please give reason_____

1.5 PBL is believed to instil in learners self-directed learning, in your opinion to what extent has PBL inculcate in learners how to learn on their own?

1.6 How would you compare learner motivation and interest in physics before studying the PBL approach and after studying the PBL approach?

1.7 How would you compare learners' retention ability of physics concept when you taught them with the traditional method and teaching them now with the PBL strategy?

2. Successes in the implementation of the PBL strategy in schools

2.1. What did you like or dislike about PBL?

2.2. What do you suggest could be done to improve what you dislike?

2.3. Why would you like or dislike continuing using the PBL approach to teach physics?

2.4. Would you recommend PBL to be used by other teachers in other schools in the circuit and the district at large? If so why and why not?

3. Challenges during the implementation of the PBL strategy

3.1. During the implementation of the strategy, did your school have enough resources to support the implementation?

3.2. What can you say about time to complete a PBL lesson and time allocated in the CAPS document per lesson per term?

3.3. Indicate why you were not able to finish a PBL lesson in 1 hour as indicated in the CAPS document.

3.4. State why you will or will not be able to complete the annual teaching plan as indicated in the CAPS document if you continue teaching your physics lessons using PBL.

3.5. To what extent did management give support to the implementation of the PBL strategy?

3.6. Can you mention any specific support that you received or lacked from management during the implementation of the PBL strategy?

3.7 What difficulties did you encounter in the implementation of PBL in your physics class?

3.8 From your experience in using the PBL approach, what are the benefits of the PBL approach to learners?

APPENDIX F

Observation protocol adapted from Reformed Teaching Observation Protocol (RTOP)

CLASSROOM OBSERVATION INSTRUMENT: (RTOP)

SECTION A:	**BACKGROUND INFORMATION**
EDUCATOR NAME:	
ANNOUNCED OBSERVATION:	
TEACHING EXPERIENCE:	
SCHOOL NAME:	
NAME OF CIRCUIT:	
DISTRICT / PROVINCE:	
GRADE/CLASS:	
DATE OF OBSERVATIONS:	
SUBJECT:	
TOPIC:	
NAME OF OBSERVER:	

SECTION B:	**CONTEXTUAL BACKGROUND AND ACTIVITIES**	
TIME (minutes)	DESCRIPTION OF EVENTS	
	Teacher activities	Students activities
0 – 10		
10 – 20		
20 – 30		
30 – 40		
40 – 50		
50 - 60		

SECTION C:	**LESSON PLAN/DESIGN & IMPLEMENTATION**						
	CRITERIA	RATING					Descriptive Comments
		0	1	2	3	4	
1	Instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.						
2	The lesson was designed to engage students as members of a learning community.						
3	In this lesson, student exploration preceded formal presentation.						
4	This lesson encouraged students to seek and value alternative modes of investigation or of problem solving						
5	The focus and direction of the lesson was often determined by ideas originating with students.						
SECTION D:	**CONTENT (Propositional Knowledge)**						
	CRITERIA	RATING					Descriptive comments
		0	1	2	3	4	
6	The lesson involved fundamental concepts of the subject.						
7	The lesson promoted strongly coherent conceptual understanding.						
8	The teacher had a solid grasp of the subject matter content inherent in the lesson.						
9	Elements of abstraction (i.e., symbolic representations, theory building) were encouraged where it was important to do so.						
10	Connections with other content disciplines and/ or real-world phenomena were explored and valued.						

SECTION E:		**CONTENT (Procedural Knowledge)**					
	CRITERIA	RATING					Descriptive comments
		0	1	2	3	4	
11	Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.						
12	Students made predictions, estimations and/or hypotheses and devised means for testing them.						
13	Students were actively engaged in thought provoking activity that often involved the critical assessment of procedures.						
14	Students were reflective about their learning.						
15	Intellectual rigor, constructive criticism, and the challenging of ideas were valued.						
SECTION F		**CLASSROOM CULTURE (Communicative Interactions)**					
	CRITERIA	RATING					Descriptive comments
		0	1	2	3	4	
16	Students were involved in the communication of their ideas to others using a variety of means and media.						
17	The teacher's questions triggered divergent modes of thinking.						
18	There was a high proportion of student talk and a significant amount of it occurred between and among students.						
19	Student questions and comments often determined the focus and direction of classroom discourse.						
20	There was a climate of respect for what others had to say.						

SECTION G: CLASSROOM CULTURE

(Teacher /Student Relationships

	CRITERIA	RATING					Descriptive comment
		0	1	2	3	4	
21	Active participation of students was encouraged and valued.						
22	Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.						
23	In general, the teacher was patient with students.						
24	The teacher acted as a resource person, working to support and enhance student investigations.						
25	The metaphor ‘teacher as listener’ was very characteristic of this classroom.						

APPENDIX G

ATTENTION: HEAD OF DEPARTMENT
KWAZULU-NATAL PROVINCIAL EDUCATION DEPARTMENT
PRIVATE BAG X9137,
PIETERMARITZBURG,
3200
ANTON MUZIWAKHE LEMBEDE BUILDING,
3RD FLOOR,
247 BURGER STREET
PIETERMARITZBURG

1ST OCTOBER 2017

FROM

PRINCIPAL RESEARCHER	**MR A OSMAN**
SCHOOL	**DULATI COMBINED SCHOOL**
ADDRESS	**P. O BOX 224 FRANKLIN 4706**
TELEPHONENUMBER	**0765542965/0835273896**
EMAIL	osmanalisul@yahoo.com

Dear Sir/Madam

RE; REQUEST FOR PERMISSION TO CONDUCT RESEARCH IN HIGH SCHOOLS

I am **OSMAN Ali**, a full-time Physical Science and Mathematics teacher of Natural Sciences Department at Dulati Combined School in Umzimkulu circuit under Harry Gwala district (**Persal: 64550907**). I am also currently enrolled with University of South Africa (UNISA) for an MSC Physics Education programme (**student number: 62004123**). As a requirement for the award of a Master of Science degree in Physics, Mathematics and Technology Education, I am investigating **the experiences of physics teachers when implementing problem-based learning.**

I would therefore like to humbly request for your permission to workshop Further Education and Training (FET) phase (grade 10 and 11) physics teachers at the Entsikeni cluster, Umzimkulu on the knowledge and skills in using PBL to teach physics and subsequently implement the strategy to assess its successes and challenges.

TARGET CIRCUITS: Umzimkulu Circuit, Entsikeni Cluster

TARGET SCHOOLS: All 8 MST Schools: (Dulati Combined School, Entsikeni Senior Secondary School, Engwaqa Senior Secondary School, Mabandla Senior Secondary School, Emsthibeni Senior Secondary School, Ginyane Senior Secondary School, Ndawana Senior Secondary School, Singisi Senior Secondary School

BRIEF OUTLOOK OF THE STUDY

Despite the effort by research in science education to introduce alternative teaching method that integrate science and engineering practice to enhance learners' problem-solving skills and motivation, schools are still using the traditional method where learners must memorise formulae and apply them in word problems. Research has shown that Problem-based learning (PBL) is an instructional method that develop in learners the skills to connect academic situation to real-world situation, promotes self-directed learning and development of 21st-century competencies and skills (Bell, 2010). To prepare students to appreciate their physical surroundings and live successfully in this global 21st-century society, there is a need to change how students are taught (Organisation for Economic Co-Operation and Development (OECD), 2007). This research is intended to develop in some selected high school physics educators the knowledge and skills in problem-based learning (PBL) and to help them implement PBL in their physics classrooms.

A summary of the study is as follows;

- A familiarization visit will be made into the schools. The reason for this visit is to create a good working relationship with physics educators.
- During the actual study, lessons will be observed to find out the kind of teaching method educators use in their physics classrooms. The first questionnaire will then be administered to determine teachers' initial knowledge and skills in PBL.
- If it is found out those teachers do not have adequate knowledge and skills in PBL, a four-weekend intervention will be organized to develop their skills and competencies in organizing PBL physics class.

- A second questionnaire will be administered the last day of the workshop to assess teachers experience and the level of acquisition of knowledge in PBL.
- A follow up visit will be done to schools. During the follow up visit lessons will be observe using the Reform Teaching Observation Protocol (RTOP) to find out how the teachers are implementing PBL in their classrooms.
- Finally, teachers will be interviewed to determine the teacher's experiences when implementing PBL in their classrooms, their successes and challenges.

The results of this research could inform stakeholders of a different approach to active learning where learners connect academic situations to the real-world, develop interpersonal skills and intrinsic motivation. This study would perhaps emphasize the need to design a curriculum that will change the way teachers teach physics at high school to meet the requirements of preparing learners to live in the global 21st-century society (Organisation for Economic Co-Operation and Development (OECD), 2007).

WHY TARGETING THESE TEACHERS

'Physics is difficult', 'Physics is difficult', 'Physics is difficult' is the slogan for learners in the Harry Gwala district and the Entsikeni circuit is not an exception. This is seen from the poor performance of learners in Physical Science in the National Senior Certificate Examination. This problem could be attributed to poor teaching method and luck of motivation on the part of the learners to study physics. Teachers at Entsikeni cluster are targeted based on this poor performance of learners in physics in the circuit. Secondly teachers in the Further Education and Training (FET) phase are targeted because they are teaching learners who are preparing to exit from basic education to find life either in higher schools of learning or in the job market. There is the need for these learners to develop the 21st-century skills needed to interact successfully in society and to prepare them for higher learning, hence the need to change the teaching strategy. PBL is a pedagogy that connect academic situation to real-world problems, improve academic performance, increase learner motivation and develop in learners the 21st-century skills.

SIGNIFICANCE OF THE STUDY

It is envisaged that the findings of this study will help in exposing the pedagogical skills that are needed to enrich knowledge economics in the 21st-century teaching and learning. Furthermore, the research findings will provide conclusive advantages of the use of the PBL strategy for teaching and learning physics. The results of this study will be made available to:

- Teachers and department officials to inform them of a different approach to active learning where learners connect academic situations to the real-world, develop interpersonal skills and intrinsic motivation.
- Department of education to provide an insight into the 21st-century teaching and learning skills (PBL) since it can positively impact on learner performance and achievement.
- High school physics teachers to be competent and proficient in the use of PBL in teaching and learning physics to enhances learners' skills such as interpersonal, communication, collaborations and presentation skills
- High school learners to realise the importance of learning on their own, and learning in groups
- Curriculum developers, science education specialists, Physical Science subject advisors so that they are better able to assistive to novice, in-service and under-qualified teachers when giving instructions in methodology workshops in physics.

There would be no interruption of all normal school programmes; I would follow the normal school timetable. Class observation will be done during the when the teacher has lessons in physics. Questionnaire administration will be done when teachers have no lessons or during break time so as not to disturb active teaching hours. Again, the workshops for professional development interventions will be done on weekends which will not interrupt normal school days. I would greatly appreciate if you can grant me the permission and opportunity to proceed with my studies as outlined above. Please do not hesitate to contact me should there be need for any further clarifications.

I have also attached instruments that I shall be making of use to collect data during this study. I have also attached proof of registration with UNISA.

Regards

Mr A OSMAN

Cell: 0765542965/0835273896
Email: osmanalisul@yahoo.com
Alternative email: osmanali201334@gmail.com

APPENDIX H

LETTER FROM THE DEPARTMENT GRANTING PERMISSION TO CONDUCT THE STUDY

education

Department:
Education
PROVINCE OF KWAZULU-NATAL

Enquiries: Phindile Duma | Tel: 033 392 1041 | Ref.:2/4/8/1387

Mr A Osman
PO Box 224
Franklin
4706

Dear Mr Osman

PERMISSION TO CONDUCT RESEARCH IN THE KZN DoE INSTITUTIONS

Your application to conduct research entitled: **"EXPERIENCE OF PHYSICS TEACHERS WHEN IMPLEMENTING PROBLEM-BASED LEARNING"**, in the KwaZulu-Natal Department of Education Institutions has been approved. The conditions of the approval are as follows:

1. The researcher will make all the arrangements concerning the research and interviews.
2. The researcher must ensure that Educator and learning programmes are not interrupted.
3. Interviews are not conducted during the time of writing examinations in schools.
4. Learners, Educators, Schools and Institutions are not identifiable in any way from the results of the research.
5. A copy of this letter is submitted to District Managers, Principals and Heads of Institutions where the Intended research and interviews are to be conducted.
6. The period of investigation is limited to the period from 01 November 2017 to 09 July 2020.
7. Your research and interviews will be limited to the schools you have proposed and approved by the Head of Department. Please note that Principals, Educators, Departmental Officials and Learners are under no obligation to participate or assist you in your investigation.
8. Should you wish to extend the period of your survey at the school(s), please contact Miss Phindile Duma at the contact numbers below
9. Upon completion of the research, a brief summary of the findings, recommendations or a full report/dissertation/thesis must be submitted to the research office of the Department. Please address it to The Office of the HOD, Private Bag X9137, Pietermaritzburg, 3200.
10. Please note that your research and interviews will be limited to schools and institutions in KwaZulu-Natal Department of Education.

Dulati Combined School
Entsikeni Senior Secondary School
Engwaqa Senior Secondary School
Ginyane Secondary School
Mabandla Senior Secondary School
Emshibani Senior Secondary School
Ndawana Senior Secondary School
Singisi Senior Secondary School

Dr. EV Nzama
Head of Department: Education
Date: 06 November 2017

..Championing Quality Education - Creating and Securing a Brighter Future

KWAZULU-NATAL DEPARTMENT OF EDUCATION
Postal Address: Private Bag X9137 • Pietermaritzburg • 3200 • Republic of South Africa
Physical Address: 247 Burger Street • Anton Lembede Building • Pietermaritzburg • 3201
Tel.: +27 33 392 1004/41 • **Fax.:** +27 033 392 1203• **Email:**Phindile.Duma@kzndoe.gov.za •**Web:**www.kzneducation.gov.za
Facebook: KZNDOE....Twitter: @DBE_KZN....Instagram: kzn_education....Youtube:kzndoe

APPENDIX I

GRANT OF PERMISSION TO USE THE REFORM TEACHING OBSERVATION PROTOCOL

On Wed, 22 Nov 2017 at 1:25, Michael Piburn <mike.piburn@asu.edu> wrote:

> Mr. Ali,
>
> You are welcome to use the RTOP in its original form and with appropriate citations. No modifications to the instrument are allowed.
>
> Good luck with your work.
>
> Mike Piburn
> Professor Emeritus
> Arizona State University
>
> Sent from my Verizon, Samsung Galaxy Tablet
>
> -------- Original message --------
> From: Ali Osman <osmanalisul@yahoo.com>
> Date: 11/20/17 11:46 AM (GMT-07:00)
> To: Michael Piburn <mike.piburn@asu.edu>
> Subject: Request for copyrights permission to use RTOP in Physics Education Research

APPENDIX J

POWER POINT PRESENTATION OF THE INTERVENTION ON PBL

INTERVENTION
WORKSHOP after JK

APPENDIX K

MATERIALS GIVEN TO TEACHERS DURING THE INTERVENTIONS

INTERVENTIONS ON PBL

EMPOWERING THE ENTSIKENE CLUSTER PHYSICS TEACHER TO USE THE PBL STRATEGY FOR TEACHING PHYSICS

TRAINING IN INNOVATIVE TEACHING METHODOLOGIES

BY

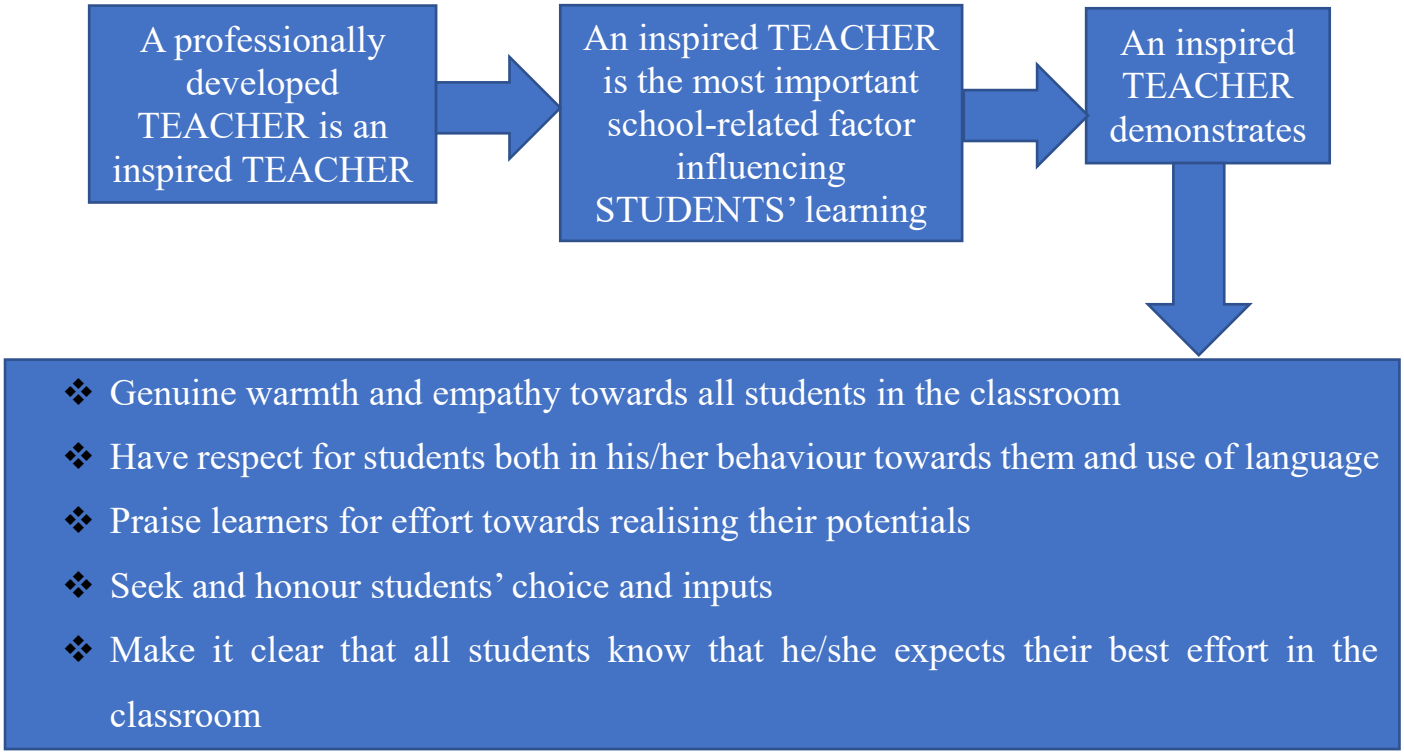
NAME: ALI OSMAN

TELEPHONE NUMBER: 0835273896/0765542965

EMAIL: osmanalisul@yahoo.com

WHY PROFESSIONAL DEVELOPMENT OF TEACHERS

Professional development is **"THE PROCESS OF IMPROVING STAFF SKILLS AND COMPETENCIES NEEDED TO PRODUCE OUTSTANDING EDUCATIONAL RESULTS FOR STUDENTS**".



OBJECTIVES OF THE WORKSHOP

- To improve the knowledge and skills of physics teachers on the use of the PBL strategy to teach physics
- To improve the knowledge and skills of physics teachers on how to develop, run and evaluate good PBL lessons
- To train physics teachers to appreciate the PBL strategy for teaching and learning physics
- To assess the PBL strategy as an instructional method for teaching and learning physics to develop conceptual understanding
- To discuss with teachers the possible ways to incorporate PBL into the traditional method of teaching and learning physics
- To discuss with teachers the advantages and disadvantages of PBL

Basic questions:

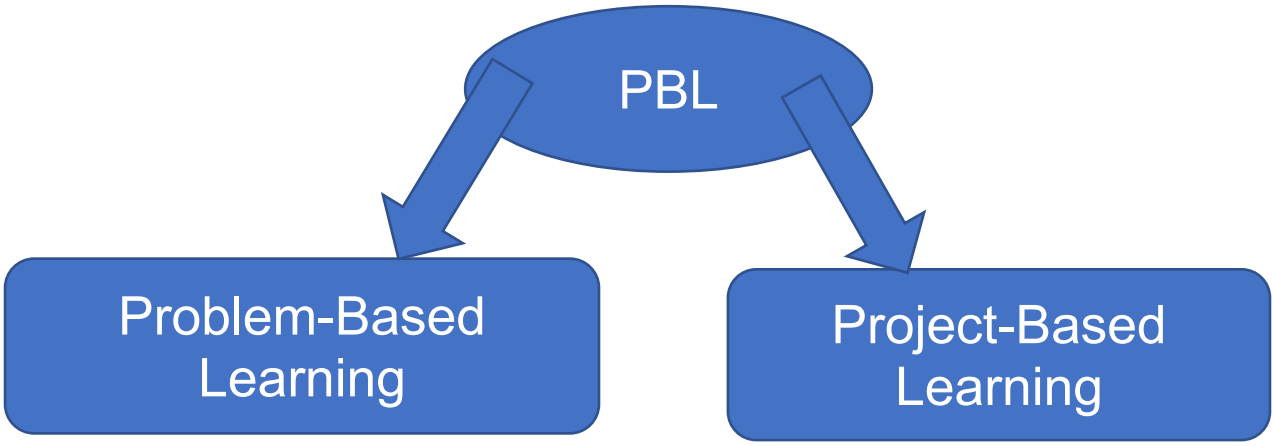
At the end of the workshop, teachers should be able to answer the following questions:

- What is Problem-based learning PBL and its core elements?
- What are the objectives of PBL?
- What are the Processes of Problem-based learning PBL?
- What are the steps in the Problem-based learning PBL process?
- What are the roles of the group members in a PBL class?
- What are the roles of the teacher in a PBL class?

SIGNIFICANCE OF THE WORKSHOP

- Physics teachers must have adequate knowledge in various teaching strategies and be able to choose the strategy that meets the needs and goals of their learners.
- PBL is a pedagogy that uses real-world problems to develop learners' knowledge in problem-solving skills.
- It is believed that a sound knowledge of physics teachers in PBL will tend to increase their competency in teaching and learning physics, improve learners' achievement, sustain learners' interest and motivate them to study physics at a higher level. This workshop is therefore intended to:

WHAT IS PBL?



NB: this workshop will focus on Problem-Based Learning

WHAT IS PROBLEM-BASEDLEARNING PBL

Problem-Based Learning (PBL) is:

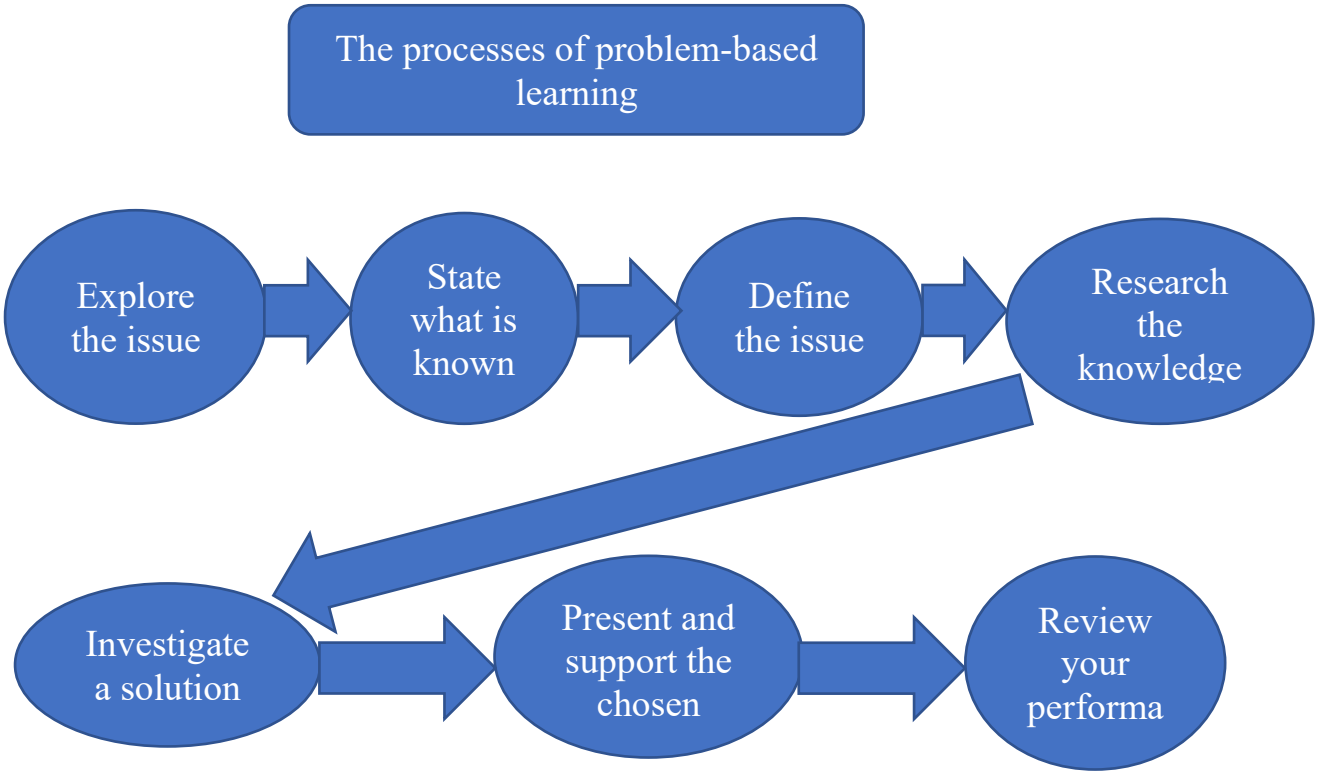
- Focused, experiential learning
- Organized around the investigation,
- Explanation, and
- Resolution of real-world problems

In PBL, students work in small collaborative groups and learn what they need to know to solve a problem.

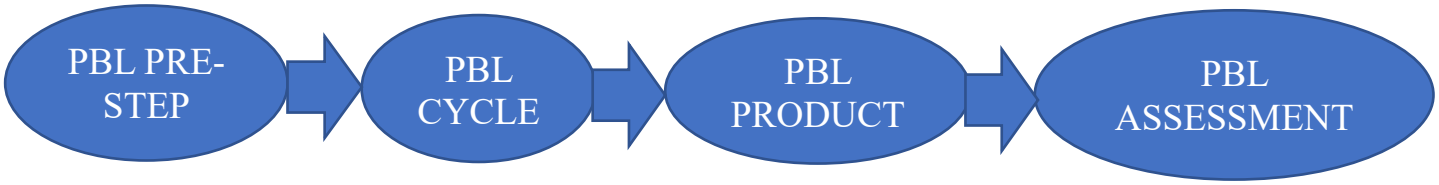
Educational Values and Principles of the Definition

- Active learning
- Student-centred learning
- Learning in context.
- Focusing on concepts
- Activating prior knowledge
- Cooperative learning
- Reflection and Feedback

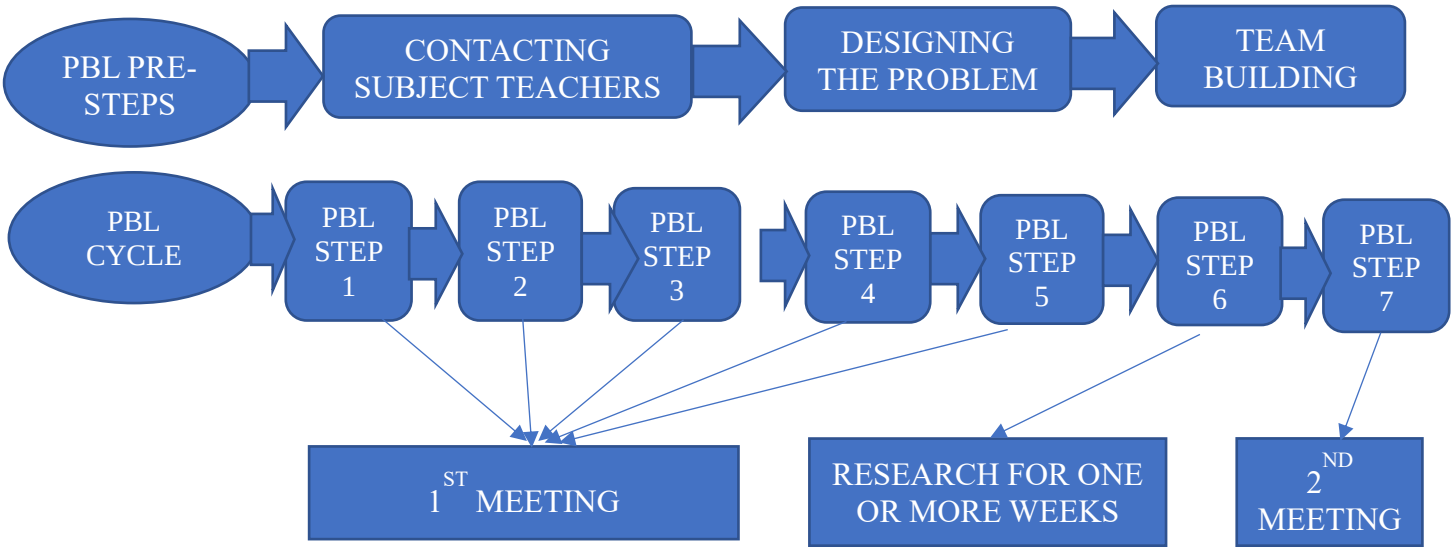
WHAT ARE THE PROCESSES OF PROBLEM-BASED LEARNING (PBL)?

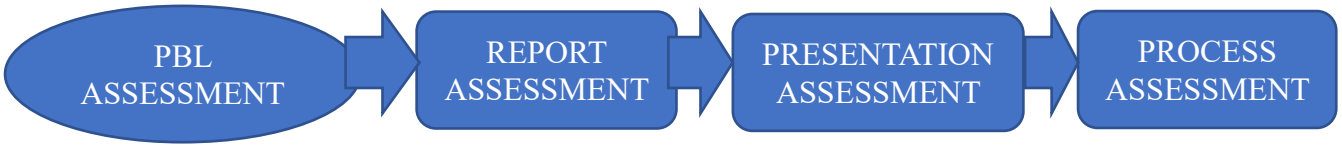


PRACTICAL APPLICATIONS OF THE PROCESSES OF PBL



In practice, in the classroom Problem-based learning (PBL)**consists of four steps. Each of these steps has additional independent steps.**





THE PBL PRE-STEPS

1. CONTACTING SUBJECT TEACHERS

Since Problem-based learning (PBL) is an interdisciplinary approach in nature, the physics teacher using PBL can involve other science teachers or other subject teachers to assist students in gathering information during research. The decision as to which subject teacher to contact depends on:

- The curriculum and contents in the syllabus that overlap
- The subject requirements
- Students' wishes
- Interest in cooperation expressed by the subject teacher

When to Contact Subject Teachers:

- The best moment to contact the subject teacher is prior to commencement of the problem-based learning (PBL) process.
- This gives the idea of the willingness of cooperation from other subject teachers prior to commencement of problem-based learning

Benefit of Cooperation in PBL:

The cooperation with subject teachers brings several benefits, including the following:

- It provides the assurance that the designed problems are relevant and up-to-date.
- The subject teacher is a good source of relevant and up-to-date information that students can refer to during their research.
- The subject teacher is the best assessor of discipline-related contents (final reports).
- The students will demonstrate a motivated attitude towards the report writing and the contents of the report – if they are aware that it will be assessed by a qualified assessor.
- Interdisciplinary teaching may also promote science teaching in the school

2. PROBLEM DESIGN

- Selection of problem is crucial to problem-based learning (PBL) since the success of the project depends on a problem that attracts the interest of students.
- Cooperation from all members of the group should be required to effectively solve the problem.
- Students should be made to understand that problem-based learning (PBL) is not about competition but a “joint venture”

Teachers must therefore not forget the fact that problem-based learning (PBL) is a problem-solving activity and a cross-curriculum approach to teaching

Characteristics of a Good Problem:

A good problem in problem-based learning (PBL) must have the following characteristic:

- Must be based on real-life situations
- Should be open-ended, and this gives room for different solutions
- The content objectives of the topic should be incorporated into the problems
- The interests and the needs of the students and their future careers should be considered
- Must require the cooperation from all members of the group to effectively solve it
- Must require students to make decisions or judgments based on facts and information gained from diverse information sources they used during their research.

Designing a Good Problem

The teacher using the problem-based learning PBL strategy must follow the following steps when designing a problem:

- The problem should relate to learners’ previous knowledge;
- Choose a central idea, concept or principle needed in your chosen topic and which the students are likely to encounter in professional practice in the future
- Provide a challenging title for the problem to engage student interest;

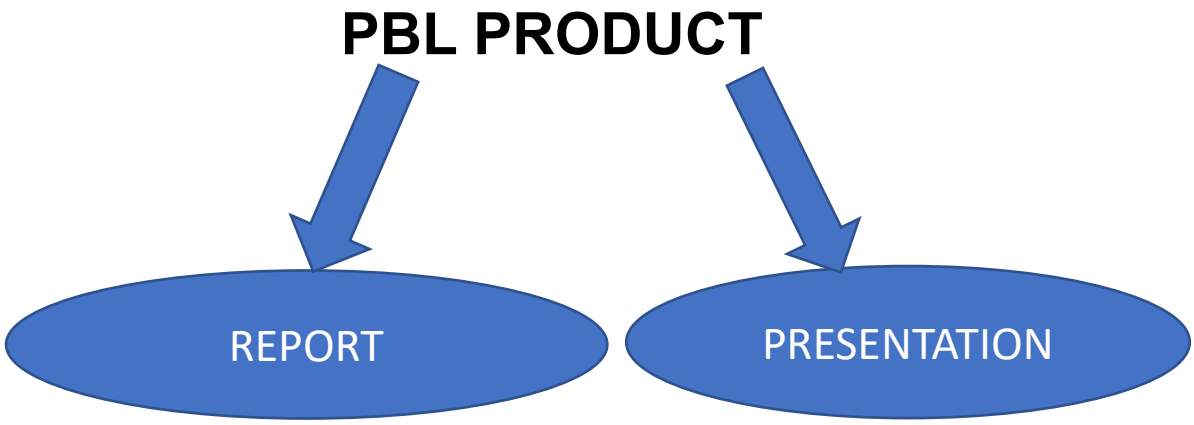
- A challenging, provocative question or a statement used as a title of the project might make the students realise that PBL could be fun, not just another boring assignment.
- The problem should be well-defined to avoid students losing too much time in trying to find the focus of their work

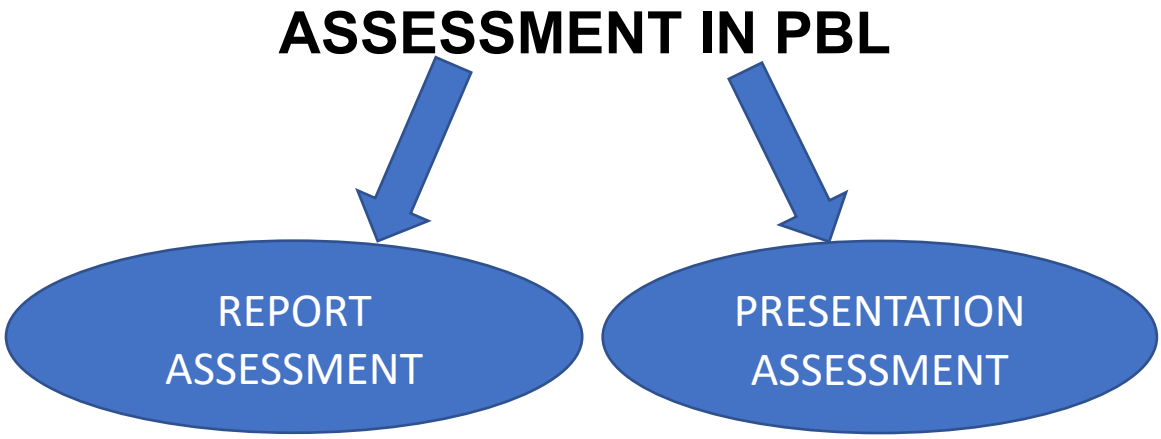
3. TEAM BUILDING

- Members that form a team in PBL must feel involved, accepted and integrated.
- The PBL teacher should consider: Interest in the problem, friendship bonds, teacher-appointed teams and language proficiency.
- The size of a group also affects the coherency of a problem-based learning (PBL) class: five (5) or four (4) members in a group are ideal.
- Each group must have members that perform the role of Chairperson, secretary, time-keeper/progress chaser, Reporter, Designer/Investigator, Editor/Evaluator

THE PBL CYCLE

	PURPOSE	ACTIVITY	TIME
PBL Step 1	Making the problem clear.	Each group of students is given a problem and tries to understand it. The roles within the group are divided.	15 minutes
PBL Step 2	Formulating questions and queries.	A brainstorming session results in the production of questions related to the problem.	15-30 minutes
PBL Step 3	Identifying knowledge and learning needs	Each group must establish how much its individual members already know about the questions from the previous step.	15 minutes
PBL Step 4	Structuring ideas.	Drawing a mind map, students decide which ideas belong together and group them around the questions. The group decides what must be learnt and what requires further research.	
PBL Step 5	Formulating the learning aims and distributing assignments among group members.	Each student is assigned the task of searching for more information on an aspect of the problem.	30 minutes
PBL Step 6	Individual activities/research	The research continues for at least a week during which time students can consult various sources and find information leading to a solution to their problem.	One to several weeks
PBL Step 7	Discussing and evaluating information.	Students try to provide an answer to the question: “Do we have enough relevant information to defend our case?” A positive answer leads to the report-writing stage while a negative answer leads the students to additional research	45 minutes





Report Assessment Form

Subject teacher: _____

Project title: _____

Please evaluate the following group achievements:

SUBJECT TEACHER

	1	2	3	4	5
Quality of work:					
- the work is well-focused	•	•	•	•	•
- the solutions are as expected (correct)	•	•	•	•	•
problem coverage complete	•	•	•	•	•
- literary sources well-utilised	•	•	•	•	•
The documentation is:					
- logically structured	•	•	•	•	•
- complete (contains all elements of a report)	•	•	•	•	•
- Technical vocabulary appropriate	•	•	•	•	•

Have the group contacted you for assistance? YES • NO •

TOTAL MARKS:_____/35 = …%

LANGUAGE TEACHER

Standard of English:	1	2	3	4	5
- Use of info (rephrasing, summarizing, discarding	•	•	•	•	•
- irrelevant information)					
- Referencing	•	•	•	•	•
- Style (corresponds to the standards of report writing, use of cohesive devices)	•	•	•	•	•
- Grammar (word order, tense forms, subject-verb agreement)	•	•	•	•	•
- Appropriate vocabulary	•	•	•	•	•
- Spelling	•	•	•	•	•
- Paragraphing and punctuation	•	•	•	•	•
Structure and layout	•	•	•	•	•

TOTAL MARKS:_____/40 = …..%

Rating Scale for Group Report
Assess the report by giving a grade from 1 – 5 (1 = not at all, 5 = very much so) in each of the following categories:

Student's name:	**1**	**2**	**3**	**4**	**5**
Contains relevant, insightful information, the solution offered is based on factual data (preferably assessed by subject teacher).					
Demonstrates awareness of structure (either Problem/Solution or IMRAD pattern).					
Shows ability to plan and complete own elements of written team report.					
Standard of English acceptable, appropriate word order, appropriate vocabulary, spelling correct.					
Meets the standards of academic writing, uses referencing, citation conventions broadly observed.					

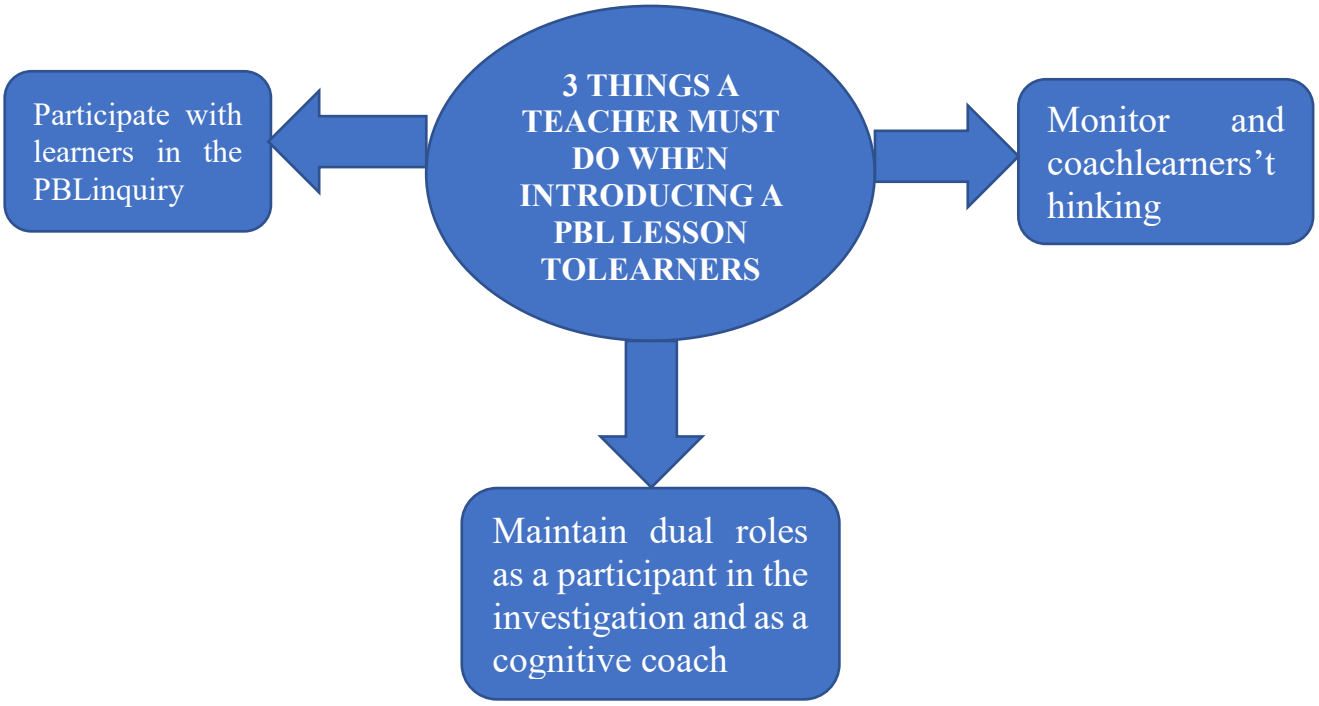
Rating Scale for Oral Presentation
Assess the student (your colleague) by giving a grade from 1 – 5 (1 = not at all; 5 = very much so)

Student's name:	**1**	**2**	**3**	**4**	**5**
The topic is relevant, well-researched and content appropriate. (subject teacher)					
Clear and well-structured organization, supported by visuals. (peers)					

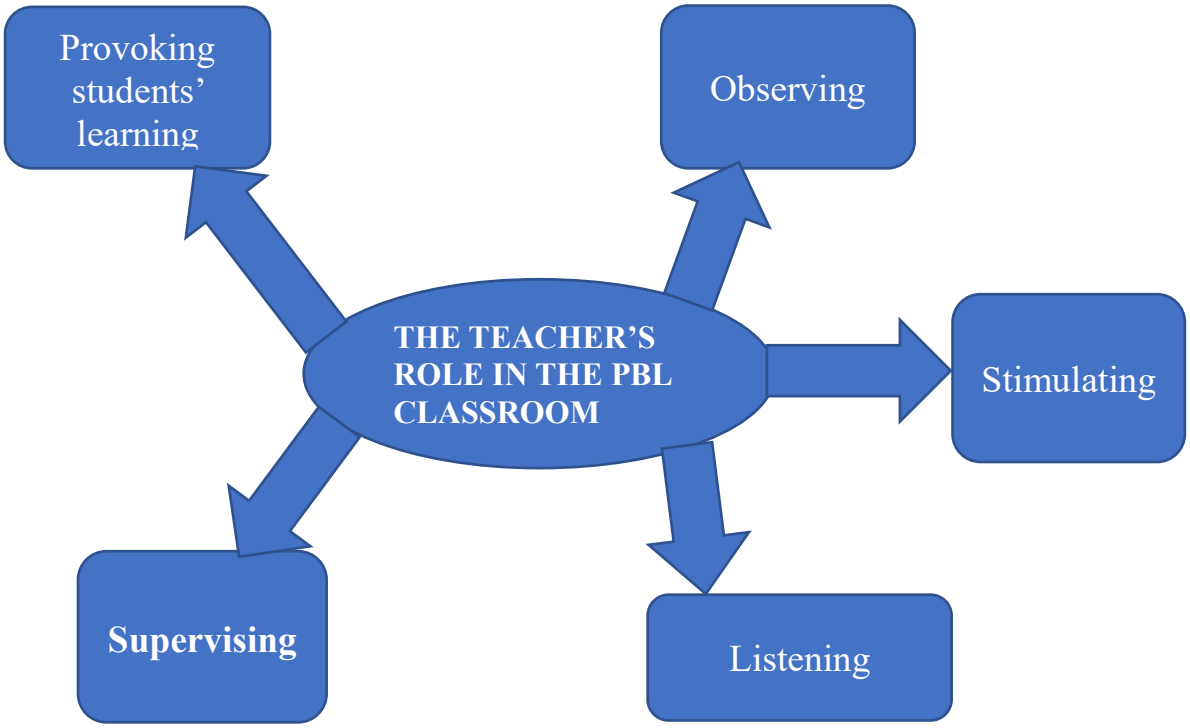
Excellent delivery, appropriate body language, can invite questions and answer them successfully. (peers)					
Good clear pronunciation, fluent with little hesitation, appropriate vocabulary, use of discourse markers. (language teacher)					

THE BASIC AIM OF PBL IS TO PROMOTE PROBLEM-SOLVING SKILLS AND MOTIVATION.

For the teacher to promote problem-solving skills through PBL, the teacher needs to perform these 3 duties



THE TEACHER'S ROLE IN THE PBL CLASS



While the teacher is performing the above role, he/she is also expected to:

- Manage discipline/behavioural problems as always
- Ask open-ended questions to help put students on focus
- Wait for students to responds to those questions and give time to process it
- Repeat or paraphrase students' ideas, but do not criticize
- Do not tell the students exactly how to do something

THE ROLE OF THE STUDENT IN A PROBLEM-BASED LEARNING (PBL)CLASS

Each student participating actively in PBL physics class has a role in the team. The roles change from time to time. The roles are:

- Team leader, whose duty it is to direct the team's work.
- Secretary, who shall take down notes of the discussion.
- Process manager, who shall listen, delegate, facilitate and always guide the group to focus on the main question.
- Investigator, who should have research skills and ability to determine relevant information.
- Time keeper, who will manage time.
- Presenter, who will present the team's work.
- Final decision maker, who identifies the best choices.
- Creative consultant, who is responsible for presenting team work through art and technology.
- Legal consultant, who checks for the accuracy of sources.

DAY 2 AND DAY3
PBL PHYSICS CLASSROOM

Planning "current electricity" using the problem-based learning PBL approach

Part 1:

1. **PBL PRE-STEPS**

Lesson: *Physics*

Class: *Grade 10*

Unit: *The impact of electrical energy on our modern lives*

Topic: *Current electricity*

Period: *8 hours*

Lesson's broad objective:

- *To identify and solve problems and make decisions using critical and creative thinking;*
- *To work effectively as individuals and with others as members of a team;*

Students' objectives and attitudes:

Concept and unit:

- *Current, resistance and voltage*
- *Simple electric circuit*
- *Verification of Ohm's law*
- *Arrangement of resistors in series and in parallel*
- *Electrical power and electrical energy*
- *Household wiring*
- *Cost of electrical energy*

Teaching-learning method and technique: *Problem-based learning*

Teaching and learning materials, devices and educational technologies: *resistors, conductors (connecting wires), circuit board, dry cells, ammeter, voltmeter, computer, course book, internet*

Ill-structured problem:

Two Physical Science students who have decided to upgrade their matric results to qualify for their chosen course at the university preferred to change school and repeat grade 11 as full-time students. They rented and shared a two bedroom flat in the vicinity of their new school. One day the two roommates argue about perceived use of electrical energy. Who should pay more towards the utility bill?

Olona**(from the kitchen)*:*** "How long does it take you to dry your hair? Your dryer is making a noise. "I'm trying to concentrate on my physics homework!"

Zomsa's retort* (from the bathroom)*: "Do you want the answer as a fraction of a year? "Then you can have fun looking up the conversion in the back of your physics textbook! "

Olona: "You've been at it for at least 20 minutes. You know, you should have to pay extra toward the electricity bill. I bet you spend an hour a day drying your hair. I think R250 extra each month would be all right."

Zomsa: "You are kidding. With you and your night light burning all night long, I bet you use much more electricity than I do! Anyway, what are you afraid of at night?"

Olona: "Yeah, but sometimes you fall asleep with your TV on. I bet that uses much more electricity than my little night light."

Zomsa: "Oh, please! That only happens once a month. How about your continuous showering? You take at least twice as long in the shower as I do. That must cost much more than running my hair dryer. What do you do in there anyway?"

Which roommate should pay more towards electricity bill, Olona or Zomsa? And how much extra?

Having solutions for these questions with your group members will be very useful for solving this problem;

- What is electrical energy and electrical power?
- How does voltage and current impact on electrical energy?
- What is the relationship between voltage, current and resistance? (investigation leading to the verification of Ohm's law)
- How does parallel and series connection impact on electrical energy distribution?
- What type of circuit connection system is preferred for household wiring and why?
- How is electrical energy produced and transmitted from the power station to our homes?
- How is electrical energy calculated and sold to the public?
- How is the cost of electrical energy calculated on appliances (hand dryer and television)?

Part 2:

2. PBLCYCLE (presenting problem-based learning (PBL)to group)

PBL STEP 1

Give the Problem Scenarios and Make the problem clear.

PBL scenario was given to students through a power point presentation in the classroom. Each group was given the problem to try to understand it. Student groups were asked: "What was intended to be told in the scenario?" Students understood the scenario and summarized while talking about current electricity.

At this stage all members understood the problem and agreed that it is a problem. Roles within the group were divided. The groups were advised to select a chair,

secretary, time-keeper, reporter, designer, editor etc. The step lasted 15 minutes. The groups were guided to take minutes of the meeting.

Minutes of first meeting;

Date of meeting:

List of members present:

Apologies for absenteeism:

Agenda:

- Discussions and understanding of the problem
- Distribution of roles within the group
- Selection of questions
- Any other matter

NB: in summary, teachers must be aware that the successful completion of PBL Step 1 is measured by the fact that:

- *Groups have been formed.*
- *Group members do not exceed 5*
- *Learners have identified a problem from the scenario*
- *Group members show interest in working on the problem*
- *Roles within the groups assigned*
- *Group members are clear about their roles*
- *Group members have adequate knowledge on writing minutes of a meeting.*

PBL STEP 2: Formulating questions and queries.

A brainstorming session results in the production of questions related to the problem. The groups discuss their ideas about the problem and generate questions that will help them break down the problem into manageable parts.

- What topic under electricity needs to be studied?
- What experiment needs to be conducted?
- What is the relationship between current, voltage and resistance?
- What is Ohm's law?
- What is electrical power?
- What is electrical energy?
- What factors affect the production of electrical energy?
- What factors influence the cost of electricity?
- How does Eskom calculate and issue electricity bills etc?

During this stage the members are not allowed to criticize each other's ideas as that will cramp creativity. No ideas should be discussed for too long, and members should encourage each other and have fun. This section takes 15 to 30 minutes.

PBL STEP 3: Identifying current knowledge and learning needs.

Each group must establish how much its individual members already know about the questions from the previous step. The groups select a topic from the previous step that is related to the problem. They are advised to choose one of the following topics among those they have generated during the brainstorming in step 2. All these topics lead to determining who pays more towards utility – Olona or Zomsa?

PBL#1

- *Electrical Power!*
- *Resistance and Ohm's law*

Participants investigate the relationship between current and voltage and determine the power of different hair dryers.

Power = Voltage x Current

PBL#2

- *Batteries and Bulbs*
- *Series and parallel combinations*

Participants investigate series and parallel connections for simple circuit and conclude which one is effective for household wiring and subsequently investigate the distribution of electrical energy to various household appliances such as the hair dryers

PBL#3

- *Parallel circuits*
- *Household wiring*
- *Reduction in loss of electrical energy during transmission*
- *Power ratings of appliances*

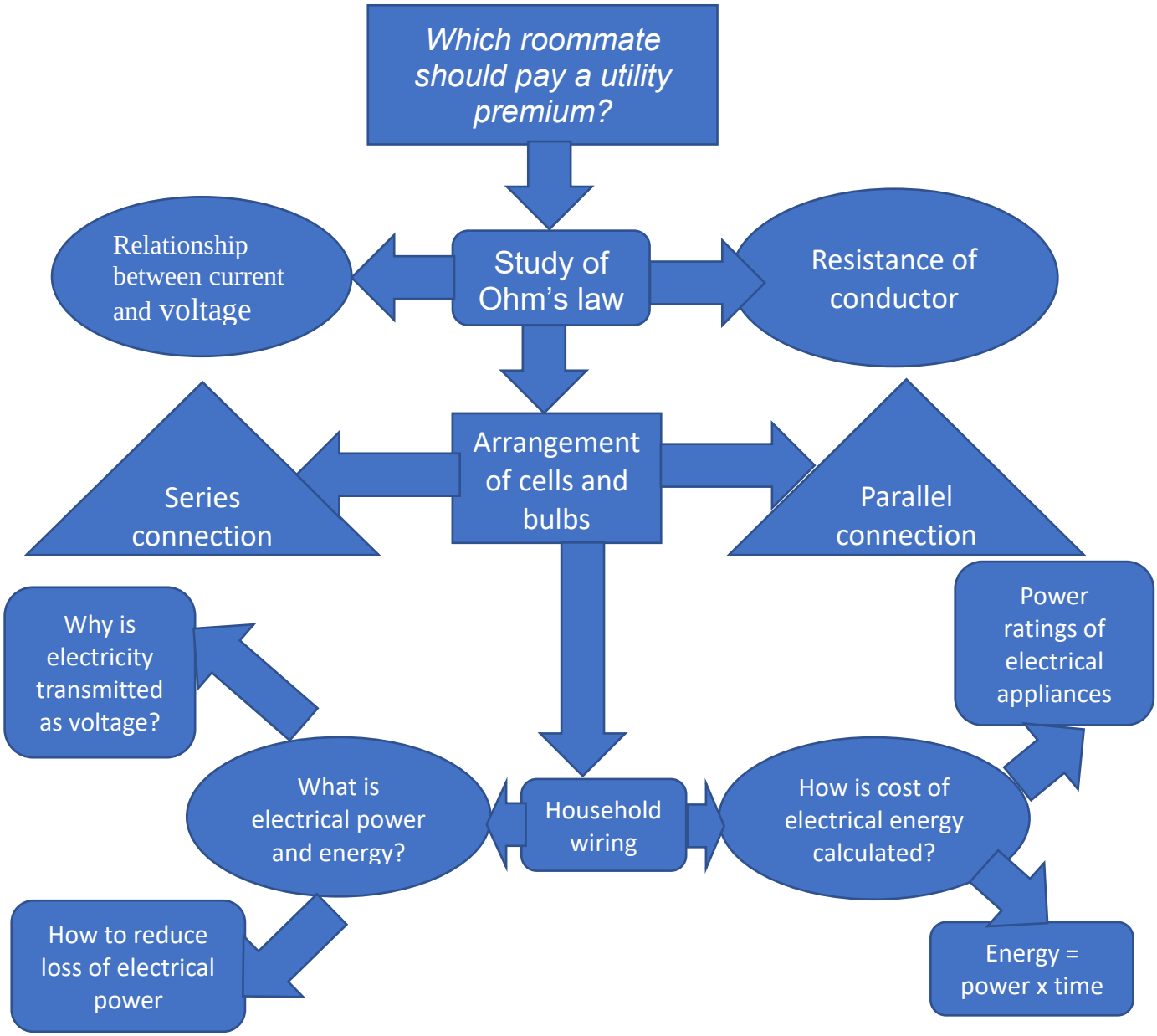
Participants investigate why house wiring is done using parallel connection. They also investigate why electricity is transmitted from power stations to our homes as voltage and not as current

The groups talk about the topic and determine what information they have and what still needs to be researched. This section takes about 15 minutes

PBL STEP 4-Structuring ideas.

The groups make a schematic structure of the problem where the causes and effects and possible solutions to the problem are indicated. In drawing a mind map, the group decide which ideas belong together and group them around the questions. The group decides what must be learnt and what requires further research. They group the ideas they gain from the questions and create a flow chart to make the ideas clearer.

SCHEMATIC STRUCTURE OF THE PROBLEM – FLOW CHART



PBL STEP 5: Formulating the learning aims and distributing assignments among group members.

For a successful PBL Step 5, the groups were encouraged to ask the following questions:

- What do we need to produce?
- What do we need to learn to be able to produce that?
- How are we expected to demonstrate the results of our research?
- What kind of information do we need to carry out our task?

The groups are advised to make a list of their learning aims. Again, they are asked to translate the learning aims into an operational plan, stating clearly who will do what.

The groups are encouraged to discuss the learning tasks which individual members will perform for the next session. The secretary records the tasks assigned to individuals.

Lessons focus or aim:

- *To analyse simple circuit leading to the verification of Ohm's law*
- *To explain the basic operations of electrical circuits*
- *To identify the factors that contribute high cost of electrical energy*
- *State and describe the energy consumption of modern electronic devices.*
- *State and explain which circuit system parallel or series is best for household wiring*
- *Identify the contribution of electrical energy to our everyday life*

This step will last for about 30 minutes.

PBL STEP 6: Individual or group activities/research

Group members engage in research to address the problem. During this step, the groups will do a lot of out-of-class research in finding a solution to the problem. The research continues for at least a week during which time the groups can consult various sources and find information leading to a solution to their problem. They may consult the internet, read books, journals, encyclopaedia, experts in the field and their subject teacher. The most common source of information is the internet. The groups were taken through a fifteen-minute demonstration on how to use the Google search engine and Google scholar to search for information on the internet. This practice when conveyed to our students will tend to make them digitally literate.

PBL STEP 7: Discussing and evaluating information

The groups are granted the opportunity of discussing their findings with other group members. During this step the group members discuss and evaluate the information each member has found during the time allocated for the out-of-class research. They are encouraged to argue their points out in defence of the solutions they had reached. The groups are advised to listen while other members are talking and wait patiently for their turn. The key aim of this stage is for the groups to share and evaluate the information they have, establish whether the information is relevant enough to solve the problem and decide whether further research is required before moving on to the reporting stage. During these collaborations the groups try to ask and answer the following question:

Do we have enough relevant information to solve the problem?

A positive answer leads to the report-writing stage while a negative answer will call for the groups to do additional research. The groups identify what they have learnt and what they do not know yet. They should also appreciate the fact that they are engaged in exchange of information. The secretary once again is expected to take minutes for the second meeting. This stage should last for at least 45 minutes. The groups conducted their discussions referring to various circuit diagrams.

Minutes of the 2nd meeting of the PBL group, held_____

Present: _____

Apologies for absence: _____

Agenda:

1. Distribution of roles

2. Discussing information on the relationship between current voltage and resistance: leading to the verification of Ohm's law

3. Putting the information together as one single idea

4. Distribution of work

5. Next meeting

6. AOB

1st agenda:

On role distribution, we agreed on the following roles: Chairperson_____, Secretary_____, Reporter _____, Timekeeper _____.

2nd agenda:

Concerning the discussions on the main research, the relationship between current, voltage and resistance:

We agreed that we have gathered enough information to report leading to the verification of Ohm's law. Together we made corrections on the information that everyone presented.

3rd agenda:

We plan to put together all the pieces of information as one document.

4th agenda:

We decided that _____ will and _____ etc. The rest of us will still try to trace additional information on the internet.

5th agenda:

The next meeting will be held on _____

PBL PRODUCT

Reporting, Presentation and supporting solution:

The groups display their findings on a piece of cardboard using appropriate graphs and circuit diagrams and explain how they arrived at the solutions. They further explain how their solution could assist in finding a solution to the main problem: “Who should pay more towards utility bills”. They are expected to indicate how data was collected to arrive at the conclusions they had drawn. They are expected to explain how the voltage and the current indicated by manufacturers on appliance tell how much energy the appliance uses when the time the appliances plugged in, is known. All three PBL topics studied by each group were presented.

ROUNDING UP WITH A LECTURE/ THE HYBRID PBL

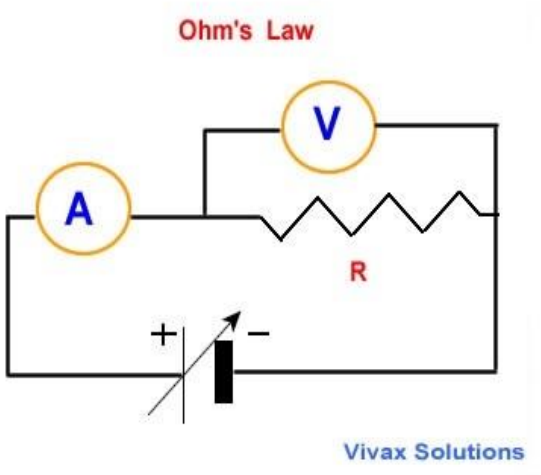
The hybrid PBL approach is employed since the strategy is new both to learners and teachers and for meeting the Department of Education’s goals of learners memorising certain key scientific concepts. Electricity and magnetism is one of the six main knowledge areas that inform the subject Physical Science in the South African science curriculum. The department of education expects learners to acquire some skills relevant to the study of Physical Science, and the PBL learning process perfectly inculcates in learners those skills.

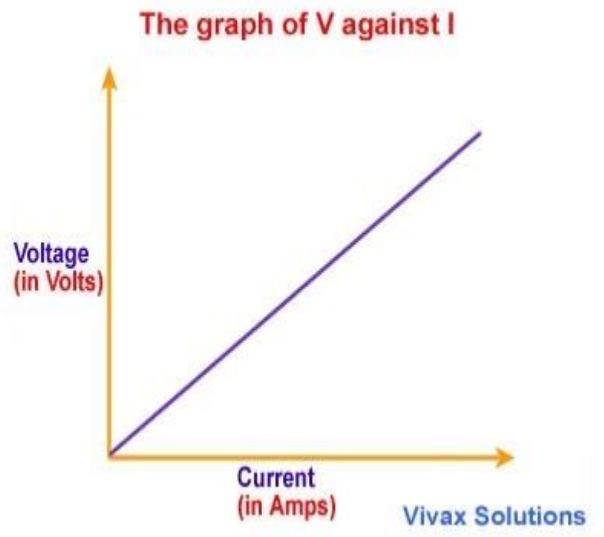
These skills include: classifying, communicating, measuring, designing an investigation, drawing and evaluating conclusions, formulating models, hypothesizing, identifying and controlling variables, and inferring, observing and comparing, interpreting, predicting, problem-solving and reflective skills.

According to the Curriculum Assessment and Policy Statement (CAPS) Physical Science document, one of the most important skills teachers of Physical Science should be aware of is that they are also expected to teach language across the Curriculum. It is therefore important to provide learners with opportunities to develop and improve their language skills in the context of learning Physical Science. Therefore, learners must be offered the opportunity of reading scientific texts, and of writing reports, paragraphs and short essays as part of the assessments as required in the PBL report-writing stage and minutes writing.

Below is a summary of what was expected from the groups in trying to answer the question as to which roommate should pay more towards utility bills.

Electrical power; resistance and Ohm's law





If the graph is a straight line that goes through the origin, then Ohm's law is correct

It states that current passing through a metallic conductor is directly proportional to the voltage across it, provided temperature remains constant.

$V \propto I$ $V = IR$ $I = \frac{V}{R}$ $R = \frac{V}{I}$

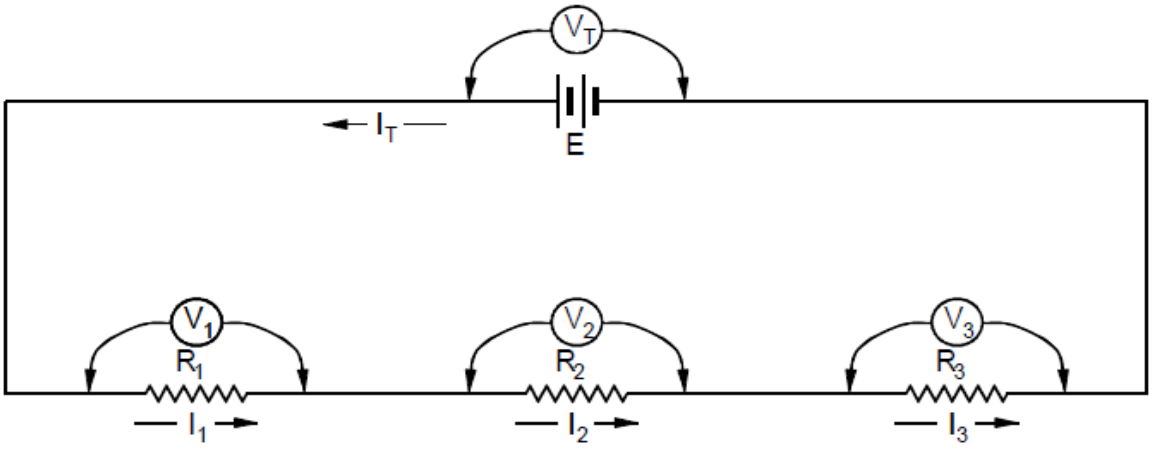
Where R is the resistance of the wire

Electric current is the rate of flow of charge around a circuit. The SI current is ampere (A)

Voltage or potential difference is the amount of energy per unit charge needed to move the charge between two points in a circuit. The unit of voltage is the volt (V)

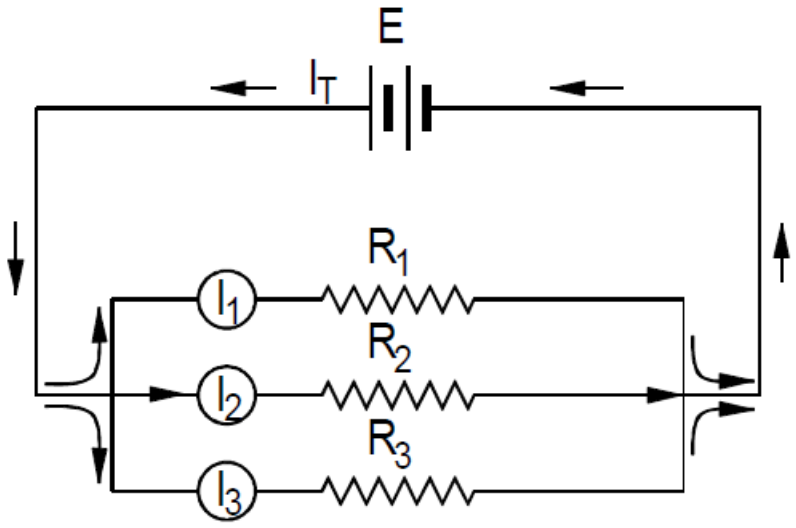
The resistance of a conductor is its opposition to the flow of current. The unit of resistance is the Ohm (Ω)

Ohm's law and series resistors



- $V = \boldsymbol{V}_1 + \boldsymbol{V}_2 + \boldsymbol{V}_3$ … the voltage is divided among the individual resistors.
- $IR = (\boldsymbol{IR})_1 + (\boldsymbol{IR})_2 + (\boldsymbol{IR})_3$ … substituting by $\boldsymbol{V = IR}$
- $\boldsymbol{IR} = \boldsymbol{I}(\boldsymbol{R}_1 + \boldsymbol{R}_2 + \boldsymbol{R}_3)$… each resistor in series circuit has the same full current of the source
- $\boldsymbol{R} = \boldsymbol{R}_1 + \boldsymbol{R}_2 + \boldsymbol{R}_3$ …
- This implies that when resistors are arranged in series, the combined resistance is the algebraic sum of the individual resistors in the circuit.

Ohm's law and parallel resistors



- $\boldsymbol{I}_T = \boldsymbol{I}_1 + \boldsymbol{I}_2 + \boldsymbol{I}_3$… the current is spread through the resistor depending on the values of the resistance in the resistor.

- $\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} \ldots$ by substituting I = $\frac{V}{R}$
- V ($\frac{1}{R}$) = V ($\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_2}$)… each resistor in parallel circuit has the same full voltage of source
- $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots$

This implies that when resistors are arranged in parallel, the combined resistance is the sum of the inverse of the individual resistors in the circuit.

Electrical power is the rate of dissipating electrical energy,

Power = current x voltage

$P = VIP = (IR)\ IP = I^2R\ P = V(\frac{V}{R})\ P = \frac{V^2}{R}$

The unit of electrical power is the watt

Electrical energy is the energy that is derived from the movement of electric charge. Electrical energy = power x time,

E = IVt E = $I^2RtE = \frac{V^2}{Rt}$

4 stages in producing electrical energy:

- A fuel is burnt to boil water to steam
- The steam makes a turbine spin
- The spinning turbine turns a generator which produces electrical energy
- The electricity goes into a transformer which produces the correct voltage

A transformer is an electrical device that changes the voltage of an alternating current supply

- Step-up transformer when it is used to increase the voltage
- Step-down transformer when it is used to reduce the voltage

The high voltage produced at power stations (250000V) is transmitted to our homes by a step-down transformer which reduces the high voltage to about 230V, too low to be dangerous

Electrical energy is transmitted from power stations to our homes through wires and cables

When current flows through wires some energy is lost as heat. The higher the current the more energy is lost in the form of heat. Following the two equations below.

$E = I^2Rt$ ---------- 1 $E = \frac{V^2}{Rt}$---------- 2

If wires of the same resistance are used to transmit electrical energy from a power station within the same time, there will be higher energy loss when it is transmitted as current according to equation 1, than when it is transmitted as voltage according to equation 2.

To reduce these losses, the national grid transmits electricity at low current and high voltage.

Designers of electrical appliances specify the voltage and current use by the appliance

How much energy an appliance uses depends on how long the appliance is plugged into the electric power.

Example

If an appliance is rated 13A and 230V and plugged for 2 hours every day for 30 days and Eskom charges R1.10 per kWh, then the cost of electricity will be;

P = IVP = 13 x 230P = 2990watts.

If it is plugged for 2 hours per day, the energy consumed will be:

E = 2990watts x2 hours E = 5980watts-hour per day.

But electricity is sold in Kilowatt hour

1 000watts = 1kilowatts 1 000watts-hour = 1kilowatts-hour

E = 5980watts-hour per day = 5.98Kilowatt-hour per day

If the appliance is used for 30 days, then the energy consumed will be:

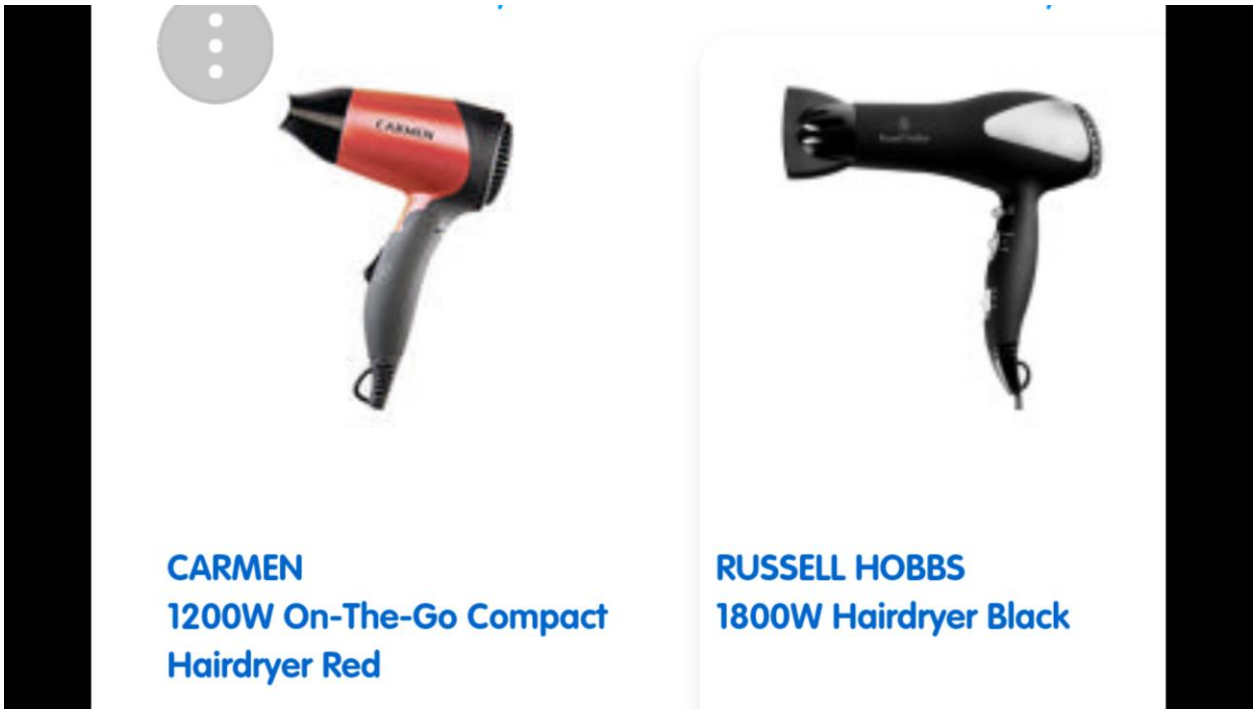
E = 5.98KwH x 30 days E = 179.4KwH

If cost of electricity is R1.10 or 110 cents per KwH, then cost of electricity will be:

179.4KwH x 110 cents = 19734 cents = R197.34 per month

Conclusion:

Suppose Zomsa has two different hair dryers which she alternates every month. If she uses a hair dryer for at least 3 hours per day for 30 days at a rate of R1.24 per kWh, the cost of electricity will be calculated as follows;



Carmen

P = 1200W

E = 1200Watt x 3hours E = 3600Watt-hour

Energy in kWh = 3.6kWh per day

Energy in kWh for 30 days = 3.6kWh x 30 = 108kWh

Rate of energy = R1.24 per kWh = 124 cents per kWh

Cost of electricity = 108 x 124

= 13 392 cents = R133.93 per month

Russell Hobbs

P = 1800W

E = 1800Watt x 3hours E = 5400Watt-hour

Energy in kWh = 5.4kWh per day

Energy in kWh for 30 days = 5.4kWh x 30 = 162kWh

Rate of energy = R1.24 per kWh = 124 cents per kWh

Cost of electricity = 162 x 124 = 20088 cents = R200.88 per month

The roommates can now calculate how much each must pay towards electricity if they know the specifications on the appliance they are using.

Activity 1

Group activity

Each group is expected to choose two topics from the Curriculum Assessment and Policy Statement (CAPS) Physical Science documenteach for grade 10 or 11 term two, brainstorm on how to write a driving question and/or ill-structured problem and prepare a PBL lesson on each.

Activity 2

Individual activity

Each member of a group is expected to teach the prepared PBL lesson in their respective schools for the two weeks ahead.

NB: lessons will be observed during the two weeks when you implement PBL in your class to assess the successes and challenges of the approach.

DAY 4

PREPARATIONS FOR IMPLEMENTATION OF THE PBL STRATEGY

Each teacher in a group decides on a topic he/she will like to teach for the two weeks during the implementation of the PBL program. Members of the groups help each other to develop an ill-structured problem on the topic they would teach for the two weeks.

Teachers reflect on PBL and answer the second questionnaire (questionnaire part 2)