The use of contextually appropriate analogies to teach direct current electric circuit concepts to isiXhosa speaking learners

Ayanda Simayi

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The use of contextually appropriate analogies to teach direct current electric circuit concepts to isiXhosa speaking learners

by

Ayanda Simayi

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Supervisor: Mrs EH Lombard

Nelson Mandela Metropolitan University

for tomorrow

DEPARTMENT OF ACADEMIC ADMINISTRATION

EXAMINATION SECTION

SUMMERSTARND SOUTH CAMPUS

PO Box 77000

Nelson Mandela Metropolitan University

Port Elizabeth

6013

Enquiries: Postgraduate Examination Officer

DECLARATION BY CANDIDATE

NAME: Ayanda Simayi

STUDENT NUMBER: 200 332 821

QUALIFICATION: Magister Educationis (Research)

TITLE OF PROJECT: The use of contextually appropriate analogies to teach direct current electric circuit concepts to isiXhosa speaking learners

DECLARATION:

In accordance with Rule G4.6.3, I hereby declare that the above-mentioned dissertation is my own work and that it has not previously been submitted for assessment to another University or for another qualification.

SIGNATURE: ______________________________

DATE: 18 March 2014

Language Declaration

I hereby confirm that I have professionally proofread and edited the thesis for the degree of Magister Educationis (Research) in the Faculty of Education at the Nelson Mandela Metropolitan University:

The use of contextually appropriate analogies to teach direct current electric circuit concepts to isiXhosa speaking learners

by

Ayanda Simayi

Sincerely

N.J.STEAR

PORT ELIZABETH
JANUARY 2014

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Siyolisile and Masibulele Simayi.

Abstract

The study investigates the effects of a professional development strategy which focuses on the use of a contextually appropriate analogy on the development of isiXhosa speaking learners‟ conceptual understanding in direct current electric circuits, where the language of instruction is English. An action research design was implemented, using three data collection cycles to document the research journey. The sample comprised of two Grade 8 and 9 classes drawn (with their respective Natural Sciences teachers) from two neighbouring, township schools in Nelson Mandela Metropolitan Municipal area.

Qualitative data were generated from interviews and classroom observation of the two science teachers (a qualified and an unqualified teacher) and learners, over a span of two years. Thematic data analysis revealed that ESL learners have alternative conceptions in simple circuits and teachers have no knowledge about analogies that can be used to teach simple circuits. A professional development was designed as a strategy, targeting the development of the Science Content Knowledge (SCK) and Topic Specific Content Pedagogic Content Knowledge (TPSCK) of the teachers. Data analysis of the professional development initiative (PDI) suggests that the teachers developed increased knowledge of concepts and teaching strategies used in teaching simple circuits, selected a contextually appropriate analogy and taught a lesson in simple circuits using the selected analogy. Analysis of learners‟ post-test results suggests that the implementation of the selected analogy developed their conceptual understanding as more learners developed the correct, scientific model of reasoning.

The results of the study suggest that when teachers are given support by being exposed to professional development; their scientific reasoning, confidence and classroom climate become more positive and learners‟ conceptual understanding improves.

Keywords: direct current electric circuit, contextually appropriate analogies, isiXhosa speaking learners, professional development.

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List of abbreviations and acronyms

ABBREVIATION	MEANING
DC	Direct current
ESL	English Second Language
PCK	Pedagogical Content Knowledge
PDI	Professional Development Initiative
SCK	Subject Content Knowledge
TSPCK	Topic Specific Pedagogical Content Knowledge

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Chapter One

Introduction

1.1 Current situation with regard to science education in South Africa

The consistently poor performance in Physical Science of Eastern Cape learners is a great cause for concern. According to the 2012 report produced by the Eastern Cape Department of Education on the performance of all the learners registered in the Eastern Cape, the number of learners registered for Grade 12 Physical Science decreased from 26367 in 2011 to 25603 in 2012, showing a drop of 764 learners (Eastern Cape Department of Education, 2013, pp. 16-17). The quality of the learners‟ performance levels also dropped dramatically as in 2012 only 23, 4% of the Grade 12 Physical Science learners attained the minimum Level Two (30-39%) pass requirement, while 12, 5% achieved a Level Three (40-49%) and 1,7% received a Level 7 (80-100%) score.

Natural Sciences in Grade 8 and 9 Eastern Cape schools is also affected by the same low performance rate problem, so that some schools have discontinued with Physical Science in Grade 10. Based on personal experience in a previous school where I worked, only 13 out of 78 Grade 8 children in 2009 managed to achieve a Level Two pass (30% to 39%) in Natural Sciences. Of the thirteen, only eight learners proceeded with Physical Science from 2009 to 2010. In 2011, the situation became worse as there was no Physical Science class in Grade 10 because of poor Grade 9 learner results. However, the bleak situation in the field of Physical Science and Natural Sciences is not unique to the Eastern Cape.

The Third International Mathematics and Science Study (TIMSS) in 1996, as well as the Trends in Mathematics and Science Study (TIMSS) undertaken in 2003 revealed that South African Grade 8 learners obtained the lowest performance scores amongst 50 participating countries in both Mathematics and Science (Webb, 2009). In addition to the above studies, the Programme for International Student Assessment (PISA), conducted in 2006, revealed that South Africa‟s Grade 8 learners performed at the lowest rungs in science when compared with other nations

(Coll, Dahsah & Faikhamta; 2010; OECD, 2007a; 2007b; Sadler & Zeidler, 2009). Since the PISA and TIMMS studies focused on reading, mathematics and science they can serve as indicators of the level of scientific literacy of South African Grade 8 learners in comparison with Grade 8 learners from other countries. There is clearly a need to develop South African Grade 8 learners‟ level of scientific literacy by improving the link between scientific knowledge and the environment, as well as the ability of the learners to interpret and communicate scientific explanations in different contexts (Duschl, Schweingruber & Shouse, 2007).

Although both the TIMMS and PISA reports show a bleak picture for South African 15-year-old learners, both reports acknowledge the importance of using examples which are familiar to the learners‟ environment when assessing them. For example, PISA findings acknowledge that the knowledge assessed should not be limited to the mastery of specific scientific content (OECD, 2007a; 2007b; Sadler & Zeidler, 2009). However, the above mentioned studies did not consider the influence of having a different home language than the language of instruction on the scores of learners whose mother tongue is not English but learn through English as the Language of Learning and Instruction (Haight & Gonzales-Espada, 2009; Setati, 2008; Webb, 2010).

Mastery of learning content knowledge has been shown to include the interplay between culture, which includes language and concept-formation (Barba, 1995). Barba (1995) argues that many learners in the past have encountered school-taught science in a culturally unfamiliar way and in an unfamiliar language. This results in a knowledge gap because the learners do not have sufficient language development and tangible, every day experience of electricity from their home environment. In that instance, learners make decisions on electrical phenomena based on what they see in their social environment which may differ from what teachers focus on at school.

The extent to which home environment permeates school science has been supported by many studies (Van den Berg & Grosheide, 1997). Hence, it becomes imperative that analogies which address the context of isiXhosa speakers are selected so that learners can form mental pictures of abstract science concepts based on the existence of familiar background. Harrison (2002, p. 1) cites that “conceptual change learning” can take place if learners are interested in a subject. Therefore, it is envisaged that isiXhosa speaking learners will become interested in learning science when they see the use of analogies chosen with particular relevance to their experiences. The learning of science will be more meaningful to the learners, as the learners will see the relevance of their own culture in the teaching of science.

The influence of having a different home language from the Language of Instruction on the learning of abstract scientific concepts is particularly evident in African languages such as isiXhosa. The teaching of abstract concepts through the use of examples that learners are familiar with in particular poses challenges to teachers with isiXhosa speaking learners due to word ambiguity and the absence of terminology to describe the abstract concepts. The absence of isiXhosa terminology in textbooks to link the prior knowledge of the learners with abstract, scientific concepts is frequently cited by teachers at workshops as reasons for the poor performance in the Senior and Further Education and Training (FET) phases. Then there is the added complication of isiXhosa words with dual meanings when translated into English. An example is the term *“umbane*” in isiXhosa, which is used to both refer to the concept electricity and lightning. This may lead to learners getting confused with the difference between scientific concepts and the everyday use of the same concepts. The ambiguity may result in learners holding alternative conceptions about the nature of direct current (DC) electric circuit concepts and retard understanding of the concepts.

The resultant poor development of scientific concepts in the Senior Phase could create a knowledge gap that allows learners to pass Physical Science in the matric examinations by rote learning of formulae with little understanding of the concepts (Guler & Yagbasan, 2008; Hancock & Onsman, 2005; Harrison, 2002). Considering that I am also an isiXhosa First Language speaking science teacher who is a product of rote learning, my personal interest in initiating the study was to contribute to science education by making science concept understanding more comprehensible by bringing in the interplay between the context of English Second Language (ESL) speakers and concepts used in science.

Dreistadt (1968), as well as Kibble (2002), identified the understanding of the behaviour of DC electric circuits containing batteries, wires and light bulbs as one of the science concepts that have remained very resistant to successful teaching. One of the possible reasons suggested by Kibble (2002) for this dilemma is that learners make decisions on electrical phenomena based on what they see in their social environment which may differ from what teachers focus on at school. Some of the reasons suggested by Kibble (2002) for the challenges experienced in teaching electricity concepts include the conflict between the tangible and visible macroscopic interface versus the abstract and invisible microscopic interface on the other hand.

A contributing factor to this conflict is the challenge of using English as the Language of Learning and Teaching (LOLT) for non-English speaking learners (Edmonds, 2002; Setati, 2008). Thus, learning difficulties arise when isiXhosa-speaking learners are unable to link the existing analogies used in the science classroom with their own practical, everyday life experiences and language.

Likewise, studies contend that teachers themselves are not confident about science subject content (Heywood & Parker, 1997; Summers, Kruger & Mant, 1997). Ashton and Webb (1986, cited in Mulholland and Wallace, 2001) established that learners generally learn more from teachers who are strong willed and believe more in their teaching capabilities. Bandura (2006, p. 307) regards a belief in oneself to produce given attainments as 'self-efficacy‟. Hence, only strong-willed individuals will be motivated sufficiently to perform and accomplish set goals (Bandura & Locke, 2003; Enoch & Riggs, 1990). Mulholland and Wallace (2001) cites Bandura (1997) and Enoch & Riggs (1990) where science is viewed as an area where low teachers self-efficacy has been seen to bring a negative effect on the learners‟ abilities to get knowledge and skills. As a result, less time is spent in teaching subjects like science when teachers have low self-efficacy and are therefore, less confident (Mulholland & Wallace, 2001).

Consequently, teaching direct electric circuits is sometimes neglected because the teachers lack pedagogical content knowledge (Appleton, 2003; Summers et al., 1997). Shulman (1987, p. 8) defines pedagogical content knowledge (PCK) as "the blending of content pedagogy" into an understanding of how particular topics, problems, or issues are organised, represented and adapted to the diverse interests and abilities of learners and presented for instruction. Pedagogical content knowledge takes into account subject matter knowledge and teaching strategies of the teachers with regard to the teacher‟s specific area of expertise so as to create effective teachers (Hutchison & Padgett, 2007; Summers et al., 1997). In this study, pedagogic content knowledge addresses the question of effective teaching with regard to the teachers‟ knowledge of the content of simple circuits in order to identify the strengths and weaknesses of the teachers (Summers et al., 1997). The idea is to identify if the teachers have any alternative conceptions, and if any alternative conceptions exist then assistance will be offered in the form of In-Service-Training.

Evidently, research conducted over the years recognises that constructivist-informed teaching, conceptual change and enactivism can bring about improved science understanding (Driver & Erikson, 1983; Palmer, 2005; Sumara & Davis, 2006). More recently, literature that agrees with the constructivist-informed model has emerged from Africa on the use of the mother tongue, societal environment and code-switching as a means of improving scientific literacy and science concept understanding amongst ESL speakers (Setati et al., 2002; Webb, 2010). Despite criticism from some researchers, constructivist-informed teaching has been recognised widely in science education because it accommodates the use of the learners‟ existing knowledge which includes home language while learning new scientific information and improving scientific literacy (Driver & Erikson, 1983; Posner, Strike, Hewson & Gertzog; 1982; Schwartz et al., 2009).

Constructivism recognises the use of analogies as one of the strategies that simplify difficult concepts and bring about conceptual change (Schwartz et al., 2009). Glynn (2008) emphasises the need for a clear understanding of how analogies work by teachers who aspire to improve the learning and promotion of interest in science. In addition to constructivism, enactivism emerged as an encompassing theory where collective knowledge and individual understanding of a concept comes forth and interacts, and the teacher is seen as a cultural broker (Fenwick, 2000; Palmer, 2000; Sumara & Davis, 2006). Enactivism views knowledge as a joint action in which an individual such as a learner is viewed as part of an increasingly complex system which may be the classroom, school, area where one stays, culture, humans in general and the biosphere (Sumara & Davis, 2006). Hence, enactivism gives recognition to views which are shared by the particular community where learners stay as the learners become part of a gradually complex system with commonly shared ideas and language.

1.2 Research Problem Statement

The use of analogies to teach the abstract concepts encountered in simple circuits has been proven to be successful in promoting understanding (Guler & Yagbasan, 2008; Harrison, 2002; Hancock & Onsman, 2005). The purpose of this study is to determine whether the use of analogies which are familiar to the life experiences and language of the learners will improve the conceptual models in elementary direct current electric circuit concepts held by teachers and learners in a senior phase isiXhosa speaking classroom.

1.3 Research question and sub-questions

To address the purpose of this study, the following central research question was formulated:

> *To what extent does the use of a contextually appropriate analogy contribute to the development of elementary direct current electric circuit concepts in isiXhosa speaking Senior Phase learners and teachers*?

In the light of the above-mentioned research question, the following sub - research questions were formulated:

- How does a sample of isiXhosa speaking Grade 8 teachers teach elementary direct current electric circuit concepts to their isiXhosa speaking learners?
- Do learners and teachers have alternative conceptual models for concepts used in direct current electric circuits?
- Which analogy is considered as appropriate to the social background of the isiXhosa speaking learners?

- What are the perceptions of the teachers and learners regarding the usefulness of the selected analogy for the understanding of the elementary direct current electric circuit concepts identified?
- Is there any change in the conceptual models constructed by the learners as illustrated by the pictorial representations of their models and explanations after the use of the selected contextually appropriate analogy?

1.4 Research aim and objectives

The aim of this study is to determine to what extent an analogy selected to be contextually relevant to a group of senior phase isiXhosa speaking learners and their teachers will improve the elementary DC conceptual models held by both the learners and the teachers. Hence, this study is set to determine how the use of contextually-bound analogies will improve concept-formation of DC electricity in Grade 8 and 9 isiXhosa speaking learners and teachers.

In order to solve the above mentioned research question, the following objectives were formulated to determine how a sample of isiXhosa speaking Senior Phase teachers teach simple circuit concepts involving the behaviour of electric circuits containing batteries, wires and light bulbs (or resistors) to isiXhosa speaking learners:

- To determine the learners‟ and teachers‟ current conceptual understanding of the direct current electric circuit concepts by means of pictorial representations of their mental models and interviews;
- To conduct a workshop with the participating teachers in which they will collectively select an analogy that is contextually appropriate to isiXhosa speaking learners for the teaching of elementary direct current electric circuit concepts;
- To conduct teacher-intervention workshops facilitated by physics education experts to ensure the teachers possess the necessary pedagogical content knowledge to select and teach the appropriate analogy with competence and confidence;

- To obtain feedback from the teachers on their perceptions related to the appropriateness of the selected analogy for their Grade 8 isiXhosa speaking learners and their own conceptual understanding of the identified concepts;
- To obtain feedback from the learners on their perceptions related to the appropriateness of the selected analogies for their conceptual understanding of the taught concepts;
- To determine to what extent the selected analogies enhanced the conceptual models held by the teachers and the learners of elementary DC electrical circuit concepts as illustrated by pictorial representations of their conceptual models.

1.5 Delimitations

This study was limited to the teaching of simple circuit concepts to isiXhosa speaking Grade 8 learners in a high school where the medium of instruction is English. A simple DC circuit consists of the following components: battery, light bulbs, length of wire, switch, ammeter and voltmeter. The focus of the study will be to establish the usefulness of analogies in teaching the following components of the simple DC electric circuit:

- Electron movement as electric current where electrons move in one direction
- Electricity as having electrons which are found in the wire all the time
- Electric circuit forms an unbroken pathway
- Battery gives the push that moves the electrons
- Electric current is not used up in the appliances but is the same all over the circuit (Summers et al., 1997).

1.6 Significance of the study

The study is aimed at ESL learners who lack meaningful understanding of science mainly due to the use of English as the language of instruction. School and population demographics at large show that there is a shortage of professionals with a science background, especially in the Black communities. Therefore, the study aims at rousing learner interest in science by introducing simple and effective ways such as analogies to make science understandable. Also, the study intends to enhance the subject matter knowledge and teaching strategies of ESL teachers who are also hesitant about their ability to teach science effectively due to the lack of subject matter knowledge and constructivist-teaching strategies such as analogies. The focus on the PCK and in particular Topic Specific Pedagogical Content Knowledge (TSPCK) is also significant.

1.7 Clarification of concepts

This section intends to clarify concepts used in learning and teaching of DC electric currents so that the reader may get the correct meaning of the term.

1.7.1 Direct-current (DC) electric circuit

An elementary direct current electric circuit consists of a battery, connecting wires and a resistor which in this instance, the resistor is a light bulb (Asoko, 2002; Glynn, 2008; Kibble, 2002). Heywood and Parker (1997) refer to a light bulb which is connected by connecting wires to a battery as a simple DC electric circuit. For the most part in this study, the abbreviation DC electric circuits will be used to refer to the concept of elementary direct current electric circuit which will also include the use of instruments like the ammeter and voltmeter. Figure 1.1 presents a basic universal circuit diagram showing the components of a direct current electric circuit.

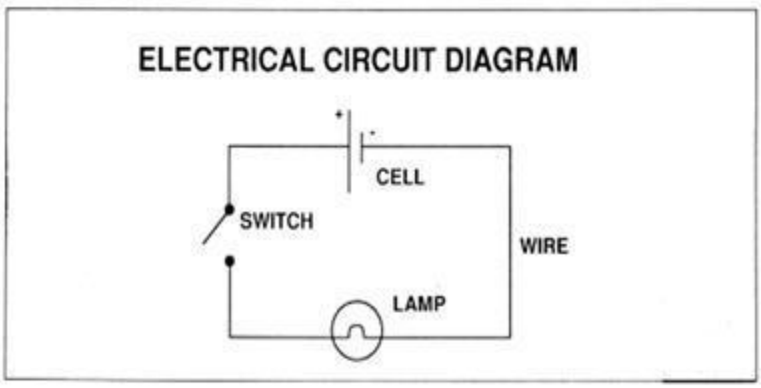

Figure 1.1: Direct current electric circuit diagram (adapted from Shipstone, 1985)**.**

1.7.2 Alternative Conceptions

Alternative conceptions are described as scientific explanations which are based on every-day life experiences and language of the individual (Baser, 2006; van den Berg & Grosheide, 1997). These conceptions are fixed firmly in the life-world of the individual and are most often inaccurate and different from established scientific truth (Baser, 2006; Palmer, 2005). Baser and Geban (2006, p. 244) refer to learners‟ intuitive ideas as alternative conceptions. Likewise, Palmer (2005) regards learners‟ views and ideas that come from home which may be inconsistent with what is taught at school as alternative conceptions. The commonly used term for children‟s intuitive ideas about science in research studies is misconceptions (Palmer, 2005).

However, Read, George and Masters (2007) criticise the use of the term „misconception‟ because they believe it puts more emphasis on mistakes found in learners‟ conceptions. Therefore, the term „alternative conception‟ will be used in this study when referring to learners‟ intuitive ideas and knowledge from the social environment. The views that learners and teachers have may in some cases be compatible or incompatible with Western scientific ideas (Read et al., 2007). The aforesaid statement brings us to the general view that not all environmental prior knowledge is faulty, hence my preference for the term „alternative conceptions‟ which accommodates both perspectives of the learners‟ knowledge.

1.7.3 Conceptual Change

Changing learners‟ alternative conceptions by science teachers is referred to as conceptual change (Baser, 2006; Palmer, 2005; Posner et al., 1982). Also, Baser (2006) defines conceptual change as the ability of teachers to change the learners‟ prior knowledge which may be inconsistent with new scientific knowledge which is taught at school. In addition, Baser and Geban (2007) cite four prerequisites which are required so that conceptual change can take place, namely, learners‟ dissatisfaction with existing conception, clarity of new target concept, possibility of solving problem using the new target concept and finally, fruitfulness of solving future problems using the target concept (Baser & Geban, 2007; Posner et al., 1982). The need for conceptual change is based on the idea that learning is an activity which needs learners to think and reason (Baser, 2006; Posner et al., 1982; Read et al., 2007).

1.7.4 Contextually appropriate analogies

Analogies are stories or visual representations of mental images which have been formed from the learners‟ pre-existing social world (Asoko & de Boo, 2001; Aubusson, Harrison & Ritchie, 2006; Duban, 2008). Equally, analogies can have positive mappings when compared to the new target concept (Duit & von Rhoneck, 1997). Therefore, contextually appropriate analogies will be analogies which investigate positive mappings between the learners‟ language, social environment and the new intended science concept (Coll et al., 2010; Duit & von Rhoneck, 1997). Contextually appropriate analogies will take into account the learners‟ familiar knowledge from the culture of a particular group of people and in this instance, isiXhosa speaking learners coming from a low socio-economic status which is characterised by limited or no access to electricity.

1.8 Division of chapters

Chapter Two gives a critical review of the latest literature related to the teaching of concepts in science and learning of DC electric circuit, the use of analogies in general and in the teaching of electricity in particular, the important role of PCK, as well as the influence of culture on learning. A variety of alternative conceptions that fall under the source-consumer model of electricity and analogies used in teaching DC electric current is described in detail. The features of analogies and examples thereof are discussed in detail; for example, the bicycle analogy, the string analogy and the water-flow analogy.

Chapter Three explains the actual study conducted and will include the motivation for choosing a qualitative action research design; detail about the participants; a description of the data collection tools, the data analysis and interpretation strategies employed, as well as the ethical considerations for the study. A description of how Cycles One, Two and Three of the educational action research was conducted is provided.

Chapter Four describes how Cycle One of the study was conducted. A two-fold problem identification process targeting the teacher and learner component of the study is discussed. Firstly, the process of identifying the type of contextually appropriate analogy used by the teachers in teaching DC electric circuits is described. Secondly, a discussion is given on how learners were investigated, searching for the presence of alternative conceptions in simple circuits and language of learning. The actual collection of raw data from Cycle One, data analysis and data interpretation is presented; followed by a discussion of the results and a plan of action to address the results obtained.

In Chapter Five the second cycle of the study, which involved the professional development intervention (PDI), is described. The theoretical framework to the PDI is discussed. This is followed by a description of the three sessions of the PDI namely, Session One (SI), Session Two (S2) and Session Three (S3). A discussion of the reflections of the participants is given after each session, followed by the selection of an analogy seen as appropriate to the context of the ESL learners.

Chapter Six discusses the implementation phase where the contextually appropriate analogy was used in teaching the lesson in simple circuits. Thereafter, a discussion is presented on the usefulness of the analogy; based on the results of the learners‟ post-diagnostic test results, including also the reflections of the teachers and learners.

In Chapter Seven, the overall findings of the study after undergoing the cyclical process of educational action research are presented. A summary of the research question, the results of the investigation and the conclusion will be the given. Chapter Seven will also address the limitations of the research, as well as recommendations for the science education profession and an indication for future research to be done.

1.9 Chapter summary

Chapter One outlined the problem statement, objectives, research question and sub-questions of the study. A discussion was presented on the significance and delimitations of the study. Key concepts such as direct current electric circuit, alternative conceptions, contextually appropriate analogies and conceptual change were clarified.

Chapter Two

Literature Review

2.1 Introduction

Chapter Two intends to give an in-depth review of literature on the use of analogies to teach topics in direct current electric circuits, specifically in the South African context with its rich multitude of cultures. Of significance to the study, literature reviewed is directed at the need to develop the isiXhosa speaking learners‟ level of scientific literacy which according to Norris and Phillips (2003) as well as Webb (2010); can be determined by assessing the ability of the learners to use scientific knowledge to solve problems. The purpose of this study is not to analyse scientific literacy, constructivist approach nor mother-tongue language instruction but to focus on how classroom teaching strategies that are based on constructivism and enactivism can bring more desirable concept-understanding of direct current electric circuit knowledge.

The dominant view in the study is that science should not emphasise scientific formalisms at the expense of interesting learning experiences that are similar to the context of the learners at home and in the community at large (Sadler & Zeidler, 2009). Hence, the learners‟ familiar experiences from home, community and classroom and language will be considered when addressing the question of choosing appropriate analogies for the participants.

2.2 Challenges of teaching direct current electric circuit concepts

Understanding the behaviour of electricity and particularly elementary direct current circuits (also known as simple circuits) has been a persistent challenge to learners, novice and experienced teachers as well (Findlay & Bryce, 2012; Kibble, 2002; Shipstone, 1985). Comprehending the abstract nature and behaviour of electricity in general remains as one of the most challenging areas in science to both young and old (Baser, 2006; Frederiksen, White & Gutwill, 1999; Kibble, 2002). Some of the suggested reasons include the following: electricity is not visible but its effects can be seen, intuitive and naïve explanations from learners which are in conflict with scientific viewpoint, teachers‟ lack of understanding of concept-formation and vocabulary used to explain abstract concepts like current and resistance (Asoko, 2002; Heywood & Parker, 1997; Kibble, 2002).

What makes learning about electricity difficult is that electricity cannot be defined in any language but the effects can be seen and felt as when individuals become electrocuted (Asoko, 2002; Shipstone, 1985). When learners are faced in the science classroom with electricity content that they do not know, they compensate and account by using their own intuitive and naïve ideas. Electricity is invisible and cannot be defined yet highly abstract and found all around us. Perhaps this is why learners and even some science teachers have alternative conceptions about how electricity works (Baser, 2006). Furthermore, Mulhall, McKittrick and Gunstone (2001) argue that learners find learning about electricity difficult because the subject content is abstract and consists mainly of models. In addition to the abstract nature of Natural Sciences concepts, the teaching strategy of teachers who have a poor understanding of Natural Sciences concepts such as electricity will have an impact on learners (Gibbons, McMahon & Wiegers, 2013).

According to Mulhall et al. (2001), a compounding factor adding to the challenge of teaching topics in electricity is that the content consists mainly of models. Although there is documented research evidence on the use of analogies as effective teaching strategies, Mulhall et al. (2001, p.580), cite that there is still a big debate about which "range and nature of models/analogies/metaphors that might be appropriate for the teaching of electricity". Recent studies have shown that even qualified teachers across all the different school phases can have difficulty in understanding and teaching electricity to learners (Findlay & Bryce, 2012; McDermott, Heron, Shaffer & Stetzer, 2006). What has also surfaced from studies is that teachers have alternative conceptions that are difficult to change (Gibbons et al., 2003).

The presence of alternative conceptions in teachers creates a dilemma where the alternative conceptions can be spread to the learners through instruction (McDermott et al., 2006). The presence of alternative conceptions in teachers indicates a gap in content knowledge, of which teachers compensate for by relying predominantly on the textbook as the main teaching strategy. When teachers rely on the textbook method, Gibbons et al. (2003), as well as Settlage and Southerland (2007), argue that learners fail to get a scientifically acceptable understanding of Natural Sciences concepts because little or no attention is given to the use of scientific models which enable learners to make observations, think, discuss and reflect on their observations. In other words, the reliance on the textbook deprives learners of opportunities where they could have reconstructed their thoughts about DC phenomena by reviewing their prior knowledge, sharing of ideas and constructing new ideas through discussion and reasoning given in class.

However, there is conclusive literature which suggests that analogies have been used successfully as constructivist teaching strategies that enhance understanding of complex concepts such as electricity in science education so that learners can be proficient in the reading, writing and understanding of science concepts (Asoko & de Boo, 2001; Chiu & Lin, 2005; Glynn, 2008). For example, extensive European studies have been carried out on the use of analogies as teaching strategies that can be used successfully to teach simple circuit concepts to secondary school learners so as to overcome the alternative conceptions that the learners come to school with (Asoko, 2002; Guler & Yagbasan, 2008).

Despite the existence of documented evidence about the use of analogies in teaching simple circuits, the studies do not cover South African isiXhosa speaking learners coming from an environment with limited exposure to electricity and learn science through the medium of English as a Second Language. One question that needs to be asked though is: if ESL speakers struggle with DC electric circuit concept-understanding at an elementary stage; is there hope for the ESL speakers to choose science as a field of specialisation? The next question that stands out would be whether there is any way of improving understanding of DC electric circuit for ESL speakers? Evidently, the documented success of analogies which spans over a long period in history affirms the view that analogies can promote meaningful concept understanding.

Turning to the historical perspective and successful implementation of analogies, Dreistadt (1968) concedes in his seminal article that the extensive use of analogies in solving scientific problems has led to great discoveries and explanations of notable scientific laws across all eras. In particular, the 18th century physicist Sir Isaac Newton used the analogy of falling apples to develop the Law of Universal Gravitation. Also, the great 20th century epoch-maker, Albert Einstein, derived the Principle of Equivalence of Gravitation and Inertia from the analogy of falling keys in a free-falling elevator (Dreistadt, 1968). In addition, White and Gribbin (2002) give detail that Stephen Hawking used at least 74 analogies to explain astrophysics and quantum ideas in his book. Therefore, if great thinkers in science have used analogical reasoning to develop laws and principles governing science, what can stop novice scientists and teachers from using analogies in elucidating abstract science phenomena?

It becomes imperative therefore to acknowledge that ESL learners are greatly limited by language when learning about DC in class (Edmonds, 2002; Webb, 2010). Webb (2010, p., 448) points out that ESL learners need to be assisted to „cross the borders between the informal language they speak at home" and the formal, academic language used in the science classroom. A question has been raised by various researchers on how best to make DC concept understanding more meaningful to learners (Edmonds, 2002; Haight & Gonzales-Espada, 2009; Probyn, 2006). Hence, research has surfaced lately that attends to the importance of the culture of ESL speakers in order to improve scientific literacy of the ESL learners, in this instance, the relationship between science and culture (Aikenhead, 2006; De Boer, 1991). Therefore, studies that look at the environment and language of the learner will be greatly considered in this study.

2.2.1 The Source-Consumer Model of electricity

Shipstone (1985) argues that learners cannot comprehend the notion of electric current, voltage and electrical energy because much of the vocabulary used in electricity has already been acquired already at home. Also, learners use their own ideas to explain what they see around them. Familiar knowledge of electricity usage and terminology becomes important in developing understanding of DC electric circuit concepts because the learning context plays a big role in scientific concept understanding (Coll et al., 2010). Shipstone (1985) draws our attention to the view that learners and some teachers believe that electric current is supplied by the battery and consumed by a resistor like a light bulb in a closed circuit.

In describing consumption, learners give their own conceptual models which Shipstone (1985) refers to as the Source-Consumer model. There are generally four alternative conceptual models held by learners about how the electric current moves in a closed circuit, namely, the unipolar, clashing currents, attenuation or consumption and sharing model (Shipstone, 1985). The unipolar model is one of the alternative conceptual models held by learners which indicate a Source-Consumer model. In the unipolar model, when resistors are connected in series; the battery is regarded as the supplier of the current which is carried by one wire to the lamp where it is used up. Secondly, the clashing currents model is shown by learners who believe that an electric current is produced from both ends of the battery terminals. Thirdly, the attenuation model depicts the view that less electric current is available at the other end after passing through a resistor like a light bulb. Lastly, the sharing model is seen from learners who believe that in a series connection, identical light bulbs will have same brightness but different electric current.

In 1994, Driver, Squires, Rushworth & Wood- Robinson reported that 85 percent of German 11 year old learners regarded the battery as a unipolar supplier of electric energy. The learners were drawn from a population of German First language speakers where the medium of learning and teaching was German. The battery was seen by learners as a source of something which was delivered to the light bulb to bring light, so the battery was seen as a storage source of electricity (Driver et al., 1994; Shipstone, 1985). Therefore, learners believed that no current was found in the return wire marked B in the diagram in Figure 2.1 of this study. The learners attached importance to only one battery terminal and one connecting wire in a circuit and the second connecting was regarded by some learners as a safety wire (Driver et al., 1994; Shipstone, 1985).

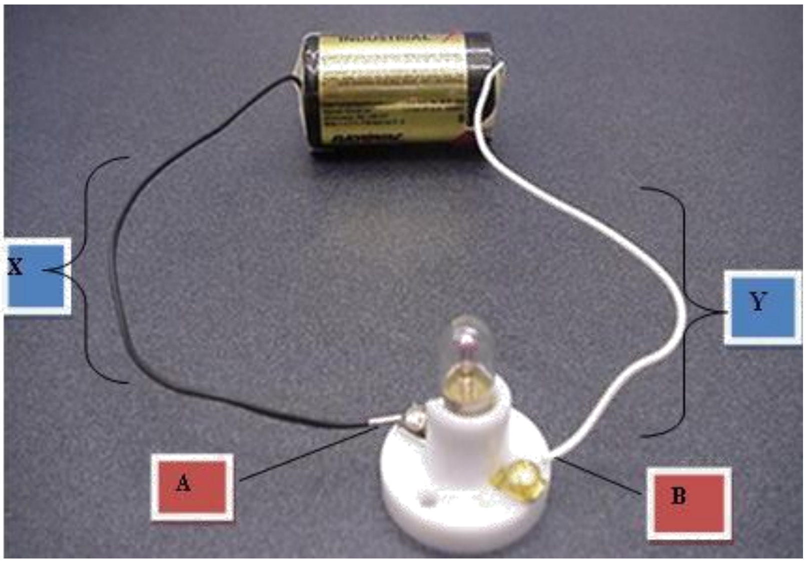

Figure 2.1: Photograph showing a battery connected to a light bulb in a closed circuit connection (adapted from teachengineering.com)

The attenuation model, which is also referred to as the consumption model, is also one of the conceptual models of the Source-Consumer model normally observed to be held by learners (Asoko, 2002; Shipstone, 1985). Learners, who held the attenuation model, believed that the electric current flows in one direction such that some current is used up by the light bulb and less current returns to the battery. In other words, learners would identify point B (see figure 2.1) as having less electric current flowing through it than would be the case at point A. However, this view is reportedly also held by physics teachers, physics students and engineering students (Heywood & Parker, 1997; Shipstone, 1985; Summers et al., 1997) and not just by learners. Likewise, extensive research conducted by Heywood and Parker (1997) and Summers et al. (1997), in England also demonstrate the existence of the Source-Consumer model in the form of the unipolar and attenuation mental models amongst learners where English is the learners‟ mother tongue and the medium of instruction and learning.

In this study, the context of the learners will be explained in terms of home language and exposure to appliances that use electricity in the learners‟ surroundings. Faced with the challenge of persistent alternative conceptions which are resistant to change, teachers need to employ teaching strategies that are going to challenge learners‟

thinking. Learners may be reluctant to change their initial views even when faced with scientific truths hence emphasis is put on teachers to develop teaching strategies which will bring about an evolution of the learners‟ views (Duschl et al., 2007). Teachers need support to develop their understanding about subject-specific knowledge on DC electric circuit, social context of the learners and the school and teaching strategies that can be employed to facilitate meaningful learning (Liston & Zeichner, 1990). Thus, the teachers‟ PCK becomes important as a vehicle of bringing about educational transformation by employing contextually-appropriate teaching strategies that will encourage a link between the learners‟ social environment and direct current electricity concept understanding (Liston & Zeichner, 1990).

2.2.2 Language and social context in learning and teaching scientific concepts

Previous European studies on science and language diversity have tended to focus on the importance of mother tongue instruction for meaningful understanding of science concepts (Setati, 2002; Heywood & Parker, 1997). Shipstone‟s (1985) study was done in England and Wales where English is the learners‟ mother tongue and is also the medium of instruction and learning. Several attempts by Aikenhead (2001) and Snively and Corsiglia (2000) emphasise the importance of incorporating language and environmental experiences of the ESL speakers to science teaching for meaningful understanding of Western science. In these studies, reference is made to the Maori people, Afro-Americans, Australian aborigines and Sub-Saharan Africa who were alienated by language as part of culture in understanding Western science (Aikenhead, 2001; Snively & Corsiglia, 2000).

The studies have been undertaken in European contexts where English is the second language to natives and foreigners in that particular country (Aikenhead, 2006; Durie, 1998; Snively & Corsiglia, 2000). Meaningful integration of the culture of the Maori, Afro-Americans, Australian aborigines and Sub-Saharan Africa indigenous groups with Western science led to a greater interest, understanding and economical emancipation of the aforesaid groups of people (Aikenhead, 2001; Durie, 1998). Setati et al. (2002), proposes that developing mother tongue literacy and code-switching is an advantage for ESL learners because learners become proficient in the mother tongue before tackling foreign language and abstract science concepts of a particular subject.

Also, Webb (2010) recognises the important role played by cognitive development in the mother tongue by suggesting that learners who are proficient in the mother tongue, obtain a solid foundation for the development of academic language. Hence, learners who developed language proficiency are able to develop academic language for the new scientific content at a later stage (Setati et al., 2002; Webb, 2010). Yet again, Durie (1998) as well as Setati et al. (2002), emphasise the importance of forming a link between the learners‟ home language, social experiences and new scientific content which is taught at school.

Concerns have been raised by many scholars about the use of traditional teaching in DC electric circuit concept understanding (Heyward & Parker, 1997; Shipstone, 1985). Teaching simple circuits in the traditional way does not lead to meaningful understanding of scientific concepts because the new concepts are in many instances inconsistent with the learners‟ pre-existing knowledge (Heyward & Parker, 1997; Shipstone, 1985; Summers et al., 1997). Also, many studies into rational conceptual change show that learners successfully resist conceptual change if the new school content is perceived as different to the known, familiar knowledge gathered from the social environment (Baser, 2006; Bennett et. al., 2005; Coll et. al., 2010).

Mindful of the fact that learners in this study are ESL speakers, recent developments in research have heightened the possibility of the development of plural meanings to scientific content reality based on the learners‟ own personal experiences about a concept (Aikenhead, 2001; Duban, 2008; Snively & Corsiglia, 2000). Barba (1995) argues that many learners in the past have encountered school-taught science in a culturally unfamiliar way and in an unfamiliar language. Unfamiliar language results in a knowledge gap because the learners do not have sufficient language development to be proficient in the language of science. Also, learners struggle to map similarities between the familiar attributes of the isiXhosa term and the scientific attributes of the term electricity (Glynn, 2007).

Brown and Brown (2010) describe an interactive discussion as a strategy where learners use previous knowledge, problem-solving ideas and group sharing to relate to new information. The use of interactive discussions implies that teachers have to check for understanding, use of analogies, meaningful teacher-learner interactions and assessments as opposed to mere note-taking (Brown & Brown, 2010). Accordingly, learners who engage in interactive discussion get appropriate chances to elaborate in detail about their views using language as a communication tool during discussion instead of mere recall and memorisation of steps and solutions to problems (Edmonds, 2002). In addition, teachers who create possibilities for interactive discussions also create opportunities amongst the learners for conceptual change where learners change their initial, incorrect views after sharing their views with other learners. Subject content knowledge as part of PCK needs to be looked at by teachers so as to ensure that learners are taught correctly.

Lee (2005) argues that the lack of good spoken and written English will create learning barriers which may cause challenges in the learners‟ development in the subject. Language is a communication tool which is used during a discussion to make known one‟s point of understanding, views and problems (Edmonds, 2002).

The dilemma posed by emphasis on English proficiency is that; subject area of instruction is limited by language of instruction. As a result, acquisition of English becomes a "*de facto* prerequisite for science learning" which determines the learners‟ science outcomes (Lee, 2005, p. 493).

Possibilities exist where some researchers may refute the view that language and social context should be considered during learning and teaching. In this event,

Vosniadou (2009) cites diSessa‟s critique of analogies based on the view that learners‟ prior knowledge is fragmentary. diSessa states that the learners‟ fragmentary knowledge in physics is based on isolated circumstances so there is no coherent, scientifically sensible view that can be traced from the learners. However, Amin (cited in Vosniadou, 2009) disputes diSessa‟s allegations by promulgating the role played by language and culture in science education.

2.3 Pedagogical Content Knowledge for direct current electric circuit

The topic dealing with simple electric circuits is conceptually abstract and is often perceived as a difficult topic to teach (Kibble, 2002). Learners have to be taught the core knowledge of concepts rather than superficial facts. The skills employed by a teacher whilst teaching has been viewed by various scholars as a window into how teachers instruct learners in class. Shulman (1986) introduced the concept of pedagogical content knowledge (PCK) to describe what the teachers do during instruction in the classroom. PCK is described as the knowledge used by teachers to transform content into a form that can be used in the classroom.

Shulman (1987) considered the ability of teachers to transform content knowledge (CK) to suit particular learners in their particular context is reported to be a unique kind of knowledge that is the domain of teachers and a part of PCK that is associated with teaching with understanding of learners‟ minds. Hence, PCK is regarded by Shulman (1987, p. 8) as "a blending of content and pedagogy" in an effort to modify topics for instruction. Shulman‟s research led to a myriad of research by various scholars into the field. The definition of PCK has evolved over the years as educational scholars reframed the original concept in various ways (Depaepe, Verschaffel & Kelchtermans, 2013). Depaepe et al. (2013), argue for an integrated approach to PCK where curriculum knowledge as well as subject matter knowledge is regarded as forming part of PCK. Mathematics teaching expanded PCK to include the term „mathematical knowledge for teaching‟ (MKT) or "content knowledge for teaching mathematics" (Depaepe et al., 2013, p. 13). In other words, PCK addressed specifically the subject content knowledge of a particular subject and how to teach the particular subject (teaching strategies).

van Driel, Veal & Janssen (2001) emphasise the view that teachers need PCK to structure the content of their lessons, to choose or develop specific representations or analogies, to understand and anticipate particular preconceptions or learning difficulties of their learners. This view is supported by Park and Oliver (2008) who emphasised the need for teachers to hold a sophisticated type of PCK if they would aim to teach science for conceptual understanding. It is no surprise that PCK is the centre of research in science education (Hume & Berry, 2011; Nilsson & van Driel, 2011). In a study by van Driel et al. in 2001, PCK was specifically categorised for science teaching with specific focus on five aspects:

- orientations toward teaching science
- knowledge of science curricula
- knowledge of students‟ understanding of science
- knowledge of assessment in science and
- knowledge of subject-specific and topic specific strategies.

PCK has been conceptualised in multiple ways. Of importance to this study is the construct of topic specific pedagogical content knowledge developed by Mavhunga & Rollnick (2011) which relates to Ball, Thames and Phelps‟ (2008) specialised content knowledge for teaching. Mavhunga and Rollnick (2011) suggest that certain topic specific components of PCK are considered when a specific topic is thought through. They identified these topics as (1) Learners‟ Prior Knowledge, (ii) Curriculum Saliency (deciding what is important for teaching and sequencing), (iii) What makes the topic easy or difficult to understand, (iv) Representations, including powerful examples and analogies, and (v) Conceptual Teaching Strategies.

Seen in the light of the reliance of electricity teaching and learning on models, analogies and metaphors (Mulhall et al., 2001), the integral part allocated to representations and the associated conceptual teaching strategies in TSPCK is of importance to this study. Another dimension of PCK that is of importance to this study is the differentiation between espoused PCK and enacted PCK, as described by Park and Oliver, 2008).

Espoused PCK includes combination of knowledges needed by a science teacher necessary to make a specific science topic comprehensible to their learners. While the espoused PCK can help science teachers to design a lesson that reflects the best practices associated with the knowledges, it is only when such knowledge get enacted in the classroom that the PCK can be called enacted PCK and as such can be observed during teaching (Park & Oliver, 2008). The focus of this research will therefore be on both the planning of how to teach simple electric circuit by the participating teachers and the actual execution of the planned lesson in order to get a sense of both their espoused and enacted PCK.

2.3.1 Theoretical framework for Professional Development Intervention

Literature review on professional development shows that there is a wide range of activities and characteristics that could be classified as professional development (Desimone, 2009). For the purpose of this study teachers‟ professional development is seen as a process in which teachers‟ progress towards the direction of responsible, independent and critical decision-making and acting in which teachers develop their own comprehension and are changing their teaching practice (Vogrinc & Zuljan, 2009).

The study takes the view that PD does not solely rest on college courses, workshops, local and national conferences but accommodates "newer and broad-based trends on how to conceptualise teachers‟ professional development" (Desimone, 2009, p. 182). The newer conceptualisations are consistent with the idea that "formal or informal learning communities among teachers can act as powerful mechanisms for teacher growth and development" (Desimone, 2009, p. 182).

Several researchers have pointed out some principles for effective professional development by synthesizing results from various research and development projects. Calderhead and Robson (1991), as well as Vogrinc and Zuljan (2009) argue that the professional development of a teacher depends on different factors; their classroom actions are significantly determined by their own experience as learners and their beliefs, conceptions of instruction, knowledge and the role of a teacher. Professional growth in teachers occurs when a professional development programme acknowledges teachers‟ personal and professional needs (Depaepe et al., 2013).

This aspect was also noted by Clark (1995) who identified principles important in the offering of professional development as being: (1) "ask for support and help", which emphasises the need for cooperation, control of professional isolation and the fear that questions reveal an individual‟s incompetence; and (2) "respect your work and show it to the others", which underlines the need to learn about one‟s own value and self-respect.

2.4 Rationale for using analogies in teaching direct current electric circuit concepts to English Second Language speakers

The use of analogies to teach the abstract concepts encountered in simple circuits has been proven to be successful in promoting understanding in a variety of contexts (Glynn, 2007; 2008). Analogies can be in the form of verbal expressions of „just like‟ or „imagine‟ or pictures and can be used to show common attributes between the familiar knowledge and new content (Glynn, 2007). Pictures pose no language constraints as predictions about what can be expected can be described in the learners‟ mother tongue.

What sets analogies apart from other strategies is that analogies work by mapping common features between the familiar base or source concept and the new, abstract target concept (Guler & Yagbasan, 2008; Glynn, 2007, 2008). Thus, analogies are easily remembered because shared similarities between the learners‟ prior knowledge and new, abstract science concept are easy to recall. Hence, analogical reasoning has been used for scientific understanding over centuries because analogies have the ability to clarify difficult, invisible electricity concepts by using existing experience (Asoko, 2002; Glynn; 2007).

Concerning the usefulness of using analogies in promoting understanding, it is important to reiterate the research question and some of the objectives of this study to ensure relevance of reviewed literature. The research question goes as follows:

> "*To what extent does the use of a contextually appropriate analogy contribute to the development of elementary direct current electric circuit concepts in isiXhosa speaking Senior Phase learners and teachers*?"

Connecting prior knowledge to new knowledge encourages learners to create mental models of the new concepts (Appleton, 2003; Foxwell & Menasce, 2004; Hancock & Onsman, 2005). Thus, analogies help learners learn better by building conceptual bridges between every day knowledge and new DC electric concepts (Glynn, 2007; Van den Berg & Grosheide, 1997). While forming mental images and building conceptual bridges, analogies become models where correct concepts between the base concept and target concepts are anchored leading to an understanding of the target concept (Van den Berg & Grosheide, 1997). Analogies are characterised by the use of stories and pictures which encourage thinking and the formation of mental images to clarify abstract concepts (Asoko & de Boo, 2001; Aubusson et al., 2006; Duban, 2008). Since analogies use verbal and pictorial expression drawn from familiar common points which include the language of the learners; a rich explanation can be drawn between the features of the base concept and the new concept.

According to Schwartz et al. (2009), pictorial representation serves as a conceptual model for thinking about how electricity concepts look like and the learners‟ reasoning given can be graded in terms of complexity from level one to level three. When learners make observations about what they see in the macroscopic world, the learners are regarded as functioning on Level One of reasoning. Learners who function on Level Two of reasoning can give reasons why certain phenomena occur by describing also non-observable features. The learners are able to give microscopic explanations of why things happen that way. For example, a learner functioning on Level Two should be able to state that the electric current that entered at one point of a single resistor will be the same all over the complete circuit because electrons come from the positive terminal to the negative terminal of the battery (Summers et al., 1997; van den Berg & Grosheide, 1997). Lastly, Level Three is characterized by learners who can make predictions and describe what would happen in new scientific situations (Schwartz et. al., 2009). In this case, learners can predict what would happen if an extra bulb is added in a parallel or series connection.

Still in another major study, Heywood and Parker (1997) claim that analogies make it possible for teachers to clarify invisible electricity concepts in DC electric circuits by using the learners‟ existing experiences. Analogy implementation does not demand much thinking because the idea is already in the mind of the learner. Therefore, analogies are strategies which are used by the constructivists to promote meaningful and effective learning because analogies recognise the importance of the learners‟ social and cultural background (Baser, 2006; Bennet et al., 2005). Previous studies reveal that analogies have the ability to quickly bring vast amounts of abstract information and connect it with the learners‟ previous experience because analogies describe a perception that two different situations are the same at some abstract level (Guler & Yagbasan, 2008; Harrison, 2002).

2.5 Theoretical perspective of analogies used in teaching direct current electric circuit

The study considers the role played by the context and culture of the participants highly; hence constructivism and interpretivism have been chosen as conceptual frameworks of the study.

2.5.1 Constructivist-informed teaching and effective learning

Teaching and learning that recognises the importance of the learners‟ experiences and social context to improve scientific understanding is referred to as constructivist-informed teaching (Palmer, 2005; Posner et al., 1982). Constructivists believe that social interaction provides learners with ways of giving meaning to the physical and social world of the community where they live. Constructivism is suggested as an epistemological and pedagogical approach because it accommodates on-going research in education which places great value on the role of analogies and prior knowledge for understanding abstract concepts (Duschl et al., 2007; Lincoln & Guba, 1985; Schwartz et al., 2009).

Posner et al. (1982, p. 1854), believe that most research in science education focuses on the „‟constructivist view"‟ of learning because learners use their existing knowledge to attribute meaning to new information. Through language, learners can share ideas and look for a solution to problems in the social world including problems in the field of science (Bentley, Ebert & Ebert, 2000; Driver & Erikson, 1983). According to Posner et al. (1982), social interaction provides learners with an avenue where learners can share ideas, negotiate meaning, and look for solutions that give meaning to new information. Equally, proponents of the cognitive constructivist school argue that learning can be initiated by mental experiences about objects they have seen in their vicinity and social interactions with adults and peers (Crotty, 1998; Palmer, 2005). Similarly, Simpson (1994) concedes that meaning should be consistent with the lived experiences of the individuals who live in a particular place.

In previous studies, Piaget (1950) noted that there is an important connection between the components of the surrounding environment where humans live and between humans themselves. A simple act of intuition and a difficult task where the individual has to reason plays a big role in giving meaning to new content (Piaget, 1950). Hence, the intention of the study is to pay attention to the simple, familiar surroundings of the learners to encourage meaningful learning and understanding of abstract science concepts used in simple circuits. In so doing, learners should be given opportunities to reflect on their thoughts and social experiences in order to change any existing alternative conceptions to give meaning to new information.

2.5.2 Conceptual change as a way of knowledge re-construction

There is consensus among researchers that alternative conceptions are difficult to change by ordinary traditional teaching (Baser & Geban, 2007; Crotty, 1998). Hence, learners have to be actively engaged in the construction and re-construction of knowledge by means of analogies which explain and predict scientific phenomena (Duschl et al., 2007; Heywood & Parker, 1997; Palmer, 2005). Under these circumstances, teaching and learning of direct current electric circuit concepts by teachers and learners respectively, can be viewed as a process of conceptual change because the challenges brought by alternative conceptions will be recognised.

To bring about conceptual change, teachers need teaching strategies that will bring opportunities of learning with understanding (Palmer, 2005; Posner et al., 1982). It is envisaged therefore that the use of analogies as models of constructivist-informed teaching will bring about conceptual change where alternative conceptions exist and lead to enhanced understanding of DC concepts. As stated herein, learning is an activity which needs learners to think and reason; therefore there is a need for conceptual change (Posner et al., 1982; Read et al., 2007). According to Posner et al. (1982), conceptual change can occur in two ways, namely assimilation and accommodation. Assimilation is observed when learners add new information into existing knowledge. Assimilation will occur when the learners add the new knowledge to their existing scheme of information which in many instances may lead to learning with no understanding.

A major study conducted by Aikenhead (2001) on cross-cultural science education reveals that Western and Aboriginal sciences can be integrated when teaching science in Grades 6 - 11. A prominent idea that surfaced from the study is that many learners initially tended to distance themselves from Western science because they did not want to be assimilated into a foreign culture (Aikenhead, 2001). However, with the use of education reform strategies that accommodate negotiation of ideas and active participation in the life-world of the individual, more Aboriginal learners embraced Western science education.

On the other hand, learners can substitute existing conceptions with new concepts because the new information makes sense. This process of conceptual change is referred to accommodation (Posner et al., 1982). What is actually envisaged in this study is accommodation as a process of conceptual change where learners get challenged to think and rethink ideas in view of new knowledge (Baser & Geban, 2007, Palmer, 2005; Posner et al., 1982). Then, too, learners will substitute existing concepts in electricity with new information because the newly-acquired information makes sense to them. Mounting criticism of conceptual change is based on the linear sequence of events that are necessary to bring about change and meaningful learning (Posner et al., 1982). The major drawback of conceptual change lies on the presumption that recognising a disagreement in conceptions will necessarily lead to dissatisfaction. Mindful of dissenting views about conceptual change, researchers generally agree on its importance as a means of improving understanding in science (Baser & Geban, 2007; Palmer, 2005; Read et al., 2007).

Many studies into rational conceptual change show that learners successfully resist conceptual change if the new school content is perceived as different from the known, familiar knowledge gathered from the social environment (Durie, 1998). In addition, motivation for this view lies in the idea that each learner‟s conceptual scheme gradually changes as the individual is exposed to new information (Driver & Erikson, 1983; Posner et al., 1982; Schwartz et al., 2009). Hence, emphasis is on the need to create teaching strategies that accommodate the learners‟ social and cultural background (Bennett et al., 2005; Coll et al., 2010; Snively & Corsiglia, 2000). Also, research covering Africa and South Africa in particular is on agreement with the international community on the use of the mother tongue and code-switching as a means of improving scientific literacy (Setati et al., 2002; Webb, 2010).

In retrospect, even though analogies have been accepted universally they are not perfect (Aubusson et al., 2006; Gentner & Gentner, 1983; Smith & Abell, 2008). The most cited limitation of analogies is that analogies cannot bring complete understanding of an abstract concept (Aubusson et al., 2006; Heywood & Parker, 1997; Smith & Abell, 2008). In the same way, Glynn (2008) highlights a limitation of analogy implementation where analogies can concurrently build scientific understanding and alternative conceptions which can lead to a conflict of understanding in learners. Likewise, Glynn (2008) cites (Duit & Glynn, 1992; 1995) who indicate that conceptual change may be promoted but simultaneously destructed by the same analogy. However, the positive gains of constructivist-informed teaching far outweigh the manner in which scientific concepts are recalled and understood in the traditional method of teaching (Duschl et al., 2007; Posner et al., 1982; Schwartz et al., 2009).

2.5.3 Ausubel's assimilation theory

Novak (2010) cites early work based on Ausubel‟s assimilation theory which was published in 1963. The assimilation theory describes how learners attribute meaning to new knowledge by making a distinction between meaningful learning and rote learning. Ausubel (1963) describes meaningful learning as the conscious and explicit connection that an individual makes between new knowledge and existing knowledge. The general idea is that learning becomes meaningful if it is stored in the individual‟s long term memory where it is connected with common, related pieces of knowledge (Ausubel, 1963).

For meaningful learning to take place, new knowledge has to be considered as part of the bigger picture of existing knowledge in the individual‟s memory (Novak, 2010).

The link between new and existing knowledge enables learners to engage in superordinate learning characterised by the development of an integrated framework of concepts where new knowledge is linked in a hierarchy with prior knowledge. For example in DC, when new concepts (such as the electric current) are connected with the learners‟ existing knowledge (lit light bulbs), learners can develop the ability to think in superordinate learning where they can comprehend the bigger idea that the electric current remains the same in a closed, series connection.

When new knowledge is unconnected to existing knowledge, it does not become meaningful and the learners learn by rote learning (Novak, 2010). Then, learners merely memorise concepts as there is a missing connection between the known and the new knowledge. Consequently, when new information is not linked to existing knowledge**,** the new knowledge is stored in an unconnected manner and becomes difficult to retrieve (Novak, 2010). The intention of the study is to move away from traditional, teaching strategies that promote rote learning towards the use of strategies that encompass constructivism and places high regard for strategies that recognise the learners‟ culture and familiar environment as a source of prior knowledge which encourages meaningful learning.

2.5.4 Vygotsky's Zone of Proximal Development

Viewed from a constructivist‟s perspective, it becomes clear that there is a strong relationship between the learners‟ prior knowledge and what can be achieved (Harland, 2003). Hence, learners attribute meaning to new content based on the close relation between the past and most recent knowledge. Seminal work by Vygotsky (1978) reveals the existence of the Zone of Proximal Development (ZPD) in learning. Vygotsky (1978) states that learners can perform certain activities without adult supervision; however, independent work is attained after following the example set by adults and peers around them.

Learners learn by emulating what they see from the surrounding environment and as a result, generate certain ways of communication as a way of expressing their thoughts. Vygotsky (1978) states that instruction takes into account the learners‟ current knowledge and skills (Harland, 2003). The difference between what the learners can do unaided and what they cannot perform on their own is referred to as the Zone of Proximal Development (Harland, 2003; Vygotsky, 1978). Based on the description of the ZPD by Vygotsky (1978), the intention of this study is to develop the ZPD of ESL learners so that they can reach a stage where they can do most science tasks confidently and without the assistance of the teacher. It is essential in the study to ensure that the teachers possess the necessary subject content knowledge and teaching skills so that they can confidently guide the ESL learners to a higher degree of ZPD.

2.5.5 Harland's Problem-Based Learning

Harland (2003) draws a link between Problem-Based Learning (PBL) and Vygotsky‟s ZPD. The study by Harland (2003) involved a group of university teachers who were trying to generate a zoology problem-based learning curriculum using action research. A striking feature of this research was that it placed great value on the view that learners learn best by doing real-life activities in a PBL curriculum rather than following traditional teaching strategies where teachers talk most of the time. In Harland‟s study, learners‟ collaborative activities were evident where learners worked with one another in a joint project. The joint activities brought out possibilities for learners to make enquiries during the investigation and broaden their current knowledge (Harland, 2003). Hence, this study advocates a shift from the traditional way of teaching where teachers do the most talking in class to a joint activity where learners engage in PBL which encourage understanding rather than rote memory.

Constructivist - informed teaching provides learners with opportunities to reason about electric phenomena instead of being given mathematical equations which need mere substitution and calculation of values (Baser, 2006; Posner et al., 1982). To illustrate, electric potential at different places in the circuit can be taught by allowing learners to reason without adhering to rules of calculating values at different points in the circuit. Hence, learners may gain a better understanding of DC concepts if there a shift from the traditional way of teaching which most often involves solving science equations by mere substitution and shifting of variables. This study encourages a change from formula-orientated traditional ways of teaching science to learner-centred approaches which accommodate the social and cultural background of the participants, including the use of the learners‟ familiar home language.

Constructivist-informed teaching takes into account the view that scientific practice cannot stay static as in the traditional way of teaching (Duschl et al., 2007; Schwartz et al., 2009). It is important to note that there is agreement on current studies about the importance of scientific modelling on learning about science (Duschl et al., 2007; Glynn, 2008; Schwartz et al., 2009). The general understanding is that constructivist-informed teaching considers the use of scientific models as structures that explain basic features of a scientific concept and help to build concept-formation. Harrison and Treagust (2000, cited in Schwartz et al., 2009, p. 633) depict a scientific model as an "abstract, simplified, representation of a system of phenomena" where key features are used to make explanations and predictions. In this case, teachers also need to be assisted with new strategies that can work as models of abstract phenomena and bring a shift from the traditional way of textbook method. Hence, teachers need to be brought for in-service training as way of refreshing their subject content knowledge and also raising their self-efficacy on science teaching (Bandura, 2006).

2.5.6 Concept-mapping and self-efficacy

As a way of enhancing understanding and forming a link between new and existing knowledge, concept-mapping is offered as alternative teaching and learning strategy (Chularut & De Backer, 2004; Novak, 2010). Findings on concept-mapping suggest that concept-mapping has a positive impact on learner achievement and self-efficacy (Chularut & De Backer, 2004). Self-efficacy is seen as the individual‟s belief about one‟s capabilities to learn tasks (Bandura, 2006). The idea is that learners and teachers as well, who believe that they are capable of carrying on with given tasks and use more learning strategies, persist with the tasks compared to individuals who do not believe (Zimmerman, Bandura & Marinez-Pons, 1992). Novak (2010, p. 09) suggests that "it is not easy for teachers" to change from programmes that use rote learning to learner-centred without getting any form of assistance.

In trying to give assistance to teachers so that they can form programmes that use memorisation, a study on In-Service Training (INSET) by Summers et al. (1997), paved a way for developing the teachers‟ subject and teaching knowledge in the topic of DC electric circuits. Following the INSET, teachers reported an improved understanding and confidence in the area of simple circuits. In the INSET, emphasis was on the use of pedagogical content knowledge (PCK) as all the ways that can be used to help learners acquire an understanding of the topic, referred to as subject-specific knowledge. In a case study reported in Summers et al. (1997), a teacher called Joan relied on her own personal understanding of concepts (subject knowledge) and her knowledge of ways in which to make ideas accessible to the learners (subject-specific knowledge).

Subject-specific knowledge requires teachers to know about learners‟ alternative conceptions as ideas that can impede correct scientific understanding. At the same time, teachers need to know about how strategies like analogies, illustrations and demonstrations can assist in reorganising the understanding of learners in science and change the incorrect, alternative conceptions (Summers et al., 1997). However, Palmer (2005) cautions that none of the recognised constructivist-informed teaching models have been universally acknowledged. For instance, Lincoln and Guba (1985) criticise constructivism-informed teaching by citing the positivists‟ views which state that the external world can be explained only in scientific language. To illustrate, positivists strongly believe that the scientist can describe reality in words that are true if they agree to facts that can be measured and false if they do not (Palmer, 2005).

Regardless of the dissenting views, Frederiksen et al. (1999), contend that they are opposed to the learning and teaching of DC electric circuits by using only abstract concepts like quantitative equations. Frederiksen et al. (1999), believe that the problem with focussing on abstractions is that; learners are not shown how the DC circuit calculations are related conceptually to what is happening in the circuit. Instead, learners are required to calculate abstract concepts like voltage by substitution of variables in an equation (e.g., *V* in Ohm‟s law). As a result, learners get an idea that DC electric circuit concepts and science in general can only be understood by manipulating mathematical equations and the learners memorise formulae in order to be able to substitute when necessary. Consequently, the learners‟ inquisitive nature disappears when they are required to engage in quantitative circuit problems and are asked to explain what has happened in the circuit (Frederiksen et al., 1999).

2.6 Analogies used as teaching strategies in direct current (DC) electric circuits

Analogies are well documented as important teaching strategies in addressing the dilemma between the microscopic and macroscopic interfaces. Gentner and Gentner (1993) regard analogies as nature‟s gift because they are easy to recall later on. Literature under review will particularly seek to determine whether a shift from a traditional way of teaching to a constructivist-teaching strategy with the use of analogies would develop improved concept understanding to the targeted learner population**.** Existing literature indicates that learning difficulties arise when learners are unable to link the existing analogies with their own everyday life experiences (Asoko, 2002; Hancock & Onsman, 2005). As a result, some learners are limited by a lack of teacher-pedagogical content knowledge (PCK) where practical, everyday experience assumed to be fundamental for understanding analogies can used (Summers et al., 1997).

The Teaching – With – Analogies (TWA) Model is suggested as a strategy which leads to successful implementation of the analogy (Glynn, 2007; 2008). Six steps of the TWA model have been suggested by Glynn (2007; 2008). Firstly, teachers should introduce the target concept which in this study will be the movement of electrons in a closed circuit. Thereafter, learners will have to be reminded about similar situations where an analogous relationship can be made between the bicycle parts and the components of a closed circuit if the bicycle analogy has been chosen as a contextually-appropriate analogy. Thirdly, similar features of the analogy and the new concept will be identified. Next, a connection has to be made between the base target and the target concept based on similar attributes between the two concepts. Weaknesses of the analogy have to be identified to avoid creating alternative conceptions, and finally, a conclusion will be made between the functions of the analogue concept and the target concept.

According to Glynn (2008), analogies should promote elaboration. Elaboration is defined as a mental process where learners form relations between the pre-existing knowledge and the new scientific term. Elaboration plays a pivotal role in constructivist-informed teaching because learners are given a rich source where they can expand their knowledge and understand future complex concepts with greater clarity. Analogies take into cognisance the learners‟ existing knowledge and map it with the new concepts, thereby making learning easier and intelligible (Glynn, 2008). For example, I know from personal experience that many learners from townships take rides on the bicycle of a peer who may be privileged to own a bicycle. Essential parts like a steering wheel, pedal, chain and brakes are generally known by the learners so a bicycle is a familiar sight to the learners and the teacher can elaborate and give a richer explanation by means of imagery while using the bicycle analogy.

Therefore, analogies will be studied based on whether there are core similarities between the familiar base knowledge and the new, target concept (Glynn, 2008). Although a significant number of analogies exist for teaching DC electricity concepts, the bicycle chain analogy, the water flow analogy and little creatures‟ analogy will be described in this study.

2.6.1 Bicycle analogy

According to Summers et al. (1997), the bicycle analogy portrays the components of the electric circuit by mapping them with the physical and macroscopic features of a bicycle. In this analogy, the pedals of the bicycle represent the battery which pushes electrons in a closed circuit. The idea is for the teacher to explain that the electrons are already found in the connecting wires so the battery gives the push necessary to set the electrons in motion. The whole bicycle chain is made up of links which are pushed simultaneously by the battery, which means that the whole circuit contains electrons even in areas where there are insulators like plastic or rubber covers around the tips of bare wires (Summers et al., 1997). The moving links are just like the electric current in a circuit and the rear cog wheel of the bicycle represents the light bulb. Resistance can be created by having someone holding the chain while the rider is still pedalling (Summers et al., 1997).

Thus, learners should be able to see that the moving bicycle links (electric current) do not get finished when the back wheel (light bulb) turns. Therefore, learners should be able to reject the attenuation conceptual model of source-consumer model of electricity (Summers et al., 1997). However, the bicycle analogy does not explain energy transformations which take place when the light bulb lights up (Summers et al., 1997). In the bicycle analogy, when a learner pushes the pedals of the bicycle, similarities must be mapped with the attribute of the battery as the pusher of electrons. The strength of the pedal indicates how much of the „push‟ of the battery is needed. However, a battery which runs out is an indication that electrons will stay still just as when a tired bicycle rider cannot continue pushing the pedals, so the links do not move (Summers et al., 1997). The learners can see that the links (electrons) are still there but they are not moving because the pedal (battery) is not giving a push which is sufficient cause motion. Similarly, Hutchison and Padgett (2007) suggest that analogies can be used as concept busters where difficult concepts can be explained by drawing similarities between what is known by the learners and the difficult, unknown concepts.

2.6.2 The String Analogy

In this analogy, a circuit is modelled as a big loop of rope with electrons as the marked points on the rope as shown in Table 2.1. In the string analogy, one person is regarded as the battery and pulls the loop through his/her hands as shown in Table 2.1. Table 2.1 presents a summary of the key points of the base concept that need to be mapped to the target concept in DC electric circuits using Glynn‟s TWA model. In order to simplify the teaching of the invisible, abstract parts of simple circuits, the string analogy portrays another person in the circle as the resistance and the person tightens the rope (see 2.1.5 of Table 2.1) while the marked points are seen to be moving at the same speed.

The base concept is the inked dot (see 2.1.2 of Table 2.1) which represents the electric charges (target concept) flowing in a closed, series circuit as shown in Table 2.1 of the study. The electric current is represented in the analogue concept by the moving dots (see 2.1.3 of Table 2.1) and the target concept is mapped clearly as the flow of charges which can be seen by learners to be moving at the same speed.

Table 2.1: The String Model Analogy and Glynn's TWA Model

Base concept	Target concept
2.1.1 Loop of string	Closed circuit
2.1.2 Dots on string	Charges
2.1.3 Moving dots	Electric current (flow of charges)
2.1.4 Pulling the string	Cell as the energy source
2.1.5 Holding the string	Resistor (bulb)
2.1.6 Two people holding the string	Resistors in series
2.1.7 Counting moving dots	Ammeter
2.1.8 All parts of the string moving at the same rate	Current is the same in all parts of a series circuit

The illustration of the principle of same speed of the electric current is crucial for modifying the consumption alternative conception model. Counting the moving dots (2.1.7 of Table 2.1) portrays the ammeter as the instrument which measures the electric current at any point in a closed circuit, of which learners must be able to predict that the electric current is going to be the same anywhere in a series connection.

This analogy is simple to understand, clearly illustrates how electric current flows in the same speed in a circuit and the energy transformations that take place can be physically be sensed by the learners. For example, friction with the hands of the resistor person means he/she can feel the electric energy transferred as heat energy. The energy is transferred very quickly, even though the rope can be moving quite slowly. This emphasizes the scientific idea that the charges are already there and they all start moving everywhere at the same time.

2.6.3 The water-flow analogy

Hutchison and Padgett (2007) give an analogous relationship between the flow of a river down a hill and the flow of the electric current in circuits. The idea of the water-flow analogy is to compare the flow of charges in a circuit to the flow of water in a river down the hill. However, such a comparison by Hutchison and Padgett (2007) about the use of the water flow analogy raises some problems. I do not accept the use of the water–flow analogy and I concur with Schwedes (1985) that the water flow analogy can cause alternative conceptions that may defeat the aim of the lesson. There are two main conceptual models of the Source-Consumer model that can be deduced from the water-flow analogy, namely, the unipolar conceptual model and the clashing currents model.

The comparison between water flowing down a river may give learners a false perception that DC electric circuits are a series of things that occur according to a certain pattern, in this case, from up the hill to a downward position. Driver et al. (1994), refer to such a pattern as the sequential model of a circuit. Critique of the water flow analogy is that it restricts thinking of the learners by neglecting the need of a complete circuit which needs to be connected by connecting wires. Hence, learners may view DC electric circuits as the downward flow of charges like water flowing down the hill without paying attention to the need for connecting wires as carriers of electrons in a closed circuit. Also, learners may succumb to the unipolar conceptual model where the battery may be seen as the supplier of water from the top of the hill. The idea of conservation of energy where electrons return to the battery is not clarified in this analogy because no water is visualised by the learners going back to the top of the hill.

Another contentious issue about that the water-flow analogy is that, it shows water coming from the top of the hill from both sides (Shipstone, 1985). An incorrect idea may be created in the minds of the learners that the battery (top of the hill) supplies electrons simultaneously from both sides of the battery terminals to the resistor (light bulb). An alternative conceptual model known as the clashing currents model can be created. Learners who have the clashing currents model believe that the electric current comes from both terminals of the battery to the light bulb or resistor (Driver et al., 1994). The correct scientific idea should be that the electric current flows in one direction and also energy is conserved in a circuit. Interactions that may take place when there is a change in one place of the circuit and these changes (energy transformations and addition of resistors in series) are not accommodated in the water-flow analogy. For example, there is no way of explaining the spontaneous lighting of the light bulb and heat energy from the lit bulb while using this analogy because only the explanation of water going downhill is given. Hidden problems may arise where the volume and velocity of the water may be compared to the electrons and no scientific truths can be given (Schwedes, 1985).

Regardless of flaws, analogies are used extensively when explaining ideas in the science classroom because analogies simplify abstract concepts and make them easier to recall (Aubusson et al., 2006; Foxwell & Menasce, 2004; Harrison, 2002).

Given this picture, it becomes imperative that education - reform strategies that accommodate constructivism-informed teaching be implemented to make science learning more meaningful for ESL speakers **(**Coll et al., 2010; Palmer, 2005).

2.7 Chapter summary

Given that the learners and teachers participating in this study are drawn from an isiXhosa-speaking community, literature reviewed presents an opportunity where the science curriculum can be linked to the ESL learners‟ prior knowledge by implementing analogies as teaching strategies that improve concept understanding and create a positive attitude towards the subject (Coll et al., 2010; Bennett et al., 2005).

Chapter Two reviewed literature that presented a historical picture that supports the idea that if teachers are given support in the form of professional development and shown how to use analogies appropriately in teaching DC electric concepts; there is hope that there will be an improvement in concept understanding in elementary direct current electric circuits by both teachers and learners in ESL speaking communities.

Chapter Three presents the philosophical grounding of the study, followed by the choice of methodology. Motivation is given on the choice of qualitative education action research methodology and how it has been used to address the research question and related objectives of the study. A detailed discussion is presented about the choice of participants, context, research design, data sources, data analysis, trustworthiness and limitations of the study.

Chapter 3
Research methodology

3.1 Introduction

This chapter intends to introduce the philosophical assumptions supporting this research, including the kinds of methods and techniques that were used to collect and analyse the data needed to solve the research question (Denzin & Lincoln, 2005; Lichtman, 2010). The purpose of this chapter is also to determine the ambit and boundaries of the selected research design and put the study amongst existing research in education action research. Since there is a variety of action research designs that could be followed to answer the research questions, this chapter provides an outline of the systematic way in which the research process has been undertaken.

The philosophical grounding of the study will be discussed in the first section of the chapter. The choice of the philosophical assumption of the interpretive approach in the field of educational action research is examined. The second section pinpoints the supporting fundamental theoretical framework which substantiates the choice of social constructivism in the study. The third section gives a detailed discussion on the appropriateness of using an action research methodology, followed by an outline of the research design with particular emphasis on my values and how they resulted in conducting the research in an ethical manner.

The research question that was designed to address the research problem is as follows:

To what extent does the use of a contextually appropriate analogy contribute to the development of elementary direct current electric circuit concepts in isiXhosa speaking Senior Phase learners and teachers?

Subsequent to the formulation of the afore-said research question, the following sub-questions were asked:

- How does a sample of isiXhosa speaking Grade 8 teachers teach elementary direct current electric circuit concepts to their isiXhosa speaking learners?
- Do learners and teachers have alternative conceptual models for concepts used in direct current electric circuits?
- Which analogy is considered as appropriate to the social background of the isiXhosa speaking learners?
- What are the perceptions of the teachers and learners regarding the usefulness of the selected analogy for the understanding of the elementary direct current electric circuit concepts identified?
- Is there any change in the conceptual models constructed by the learners as illustrated by the pictorial representations of their models and explanations after the use of the selected contextually appropriate analogy?

3.2 Philosophical basis of research

Seminal studies undertaken by Crotty (1998) established the importance of having a well-developed conceptual framework as a means of disclosing the researcher‟s beliefs, assumptions, and theories that support and lend credibility to the study. Recent work by Creswell (2009), as well as Denzin and Lincoln (2005) support

Crotty‟s early work by addressing four fundamental questions inherent in a conceptual framework, namely, the epistemology, theoretical perspective, methodology and methods. The most pertinent philosophical assumptions which guide this study have been selected in line with the above-mentioned studies.

Claims have been made in this study about what is knowledge (ontology), how researchers understand knowledge (epistemology), what values are found in knowledge (axiology) and the processes for studying; known as methodologies (Creswell, 2009; Denzin & Lincoln; 2005; Guba & Lincoln, 2005). Hence, philosophical underpinnings have been limited to those which relate to epistemological, ontological, axiological and methodological beliefs of the researcher which address the research question and sub-questions raised in this study. What follows is a discussion about the choice of social constructivism and interpretivism as paradigms used in the study (Lichtman, 2010).

3.2.1 Paradigm choice

Lichtman (2010) postulates three paradigms, namely, positivist, interpretive and constructivist. This study is aligned with the idea of a three-fold classification of paradigms as suggested by Lichtman (2010). Mindful of the various meanings of the term paradigm as suggested by Morgan (2007), this study adopts the version of paradigms as worldviews and epistemological stances as suggested by Guba and Lincoln (2005). The first fundamental perspective taken in this study is a social constructivist paradigm (Creswell, 2009; Lichtman, 2010). The choice of this paradigm is based on the idea that social constructivism accommodates the individual‟s subjective, ontological position and also includes individual and communal values of the participants in a particular residential area (Babbie & Mouton, 2001; Creswell, 2009; Lichtman; 2010).

The second fundamental perspective considered in the study is the interpretivist paradigm (Denzin & Lincoln, 2005; Lichtman; 2010). According to Denzin and Lincoln (2005), the purpose of the interpretive research is to describe and interpret reality in order to get shared meaning with other individuals who live in the same surroundings. Therefore, the interpretive paradigm has been selected because it can be implemented in individual and small groups which are studied in their own naturalistic settings (Basit, 2010; Denzin & Lincoln, 2005). Central to interpretivism is the need to reveal a deeper understanding of a particular situation in its naturalistic setting, including the language and every day way of life of individuals in that situation (Basit, 2010; Denzin & Lincoln, 2005). As an interpretive orientated study, this research has an interest in understanding the research participants‟ subjective experiences as well as the general perception held by participants whose home language is not English. Taking into consideration the role played by context when viewed naturalistically in this study, the influence of the participants‟ context can be ascribed to the natural setting rather than using specialised and tailor-made questionnaires which test pre-conceived ideas.

The choice of the two paradigms, namely social constructivism and interpretivism was based on my interpretations of reality as a researcher and on whether the research questions and objectives of the study have been addressed by the chosen paradigm. For example, social constructivism and interpretivism accommodate the view that learners may develop alternative conceptions such as those found in the Source-Consumer model because they cannot understand new concepts used in DC circuits taught at school (Asoko, 2002). The vocabulary of DC concepts such as voltage and electrical energy used in DC may be different to the learners‟ existing knowledge (Coll et al., 2010; Heywood & Parker, 1997). When learners are faced with unfamiliar knowledge, they may try to explain and give reasons to the unknown, new scientific phenomena by providing instinctive ideas as a way of explaining the new knowledge. Hence, both paradigms are relevant to my study since I am interested in understanding the subjective experiences and shared meanings of participants regarding the belief that the electric current is supplied by the battery and consumed by a resistor like a light bulb in a closed circuit so that there is less electric current available on the other connecting point of the closed circuit after the bulb has been lit.

Criticism of the epistemological stance and world-view description of paradigms is based on the idea that very little information is given about what to study and how to study that phenomenon (Schwandt, 2006). However, I do not agree with Schwandt (2006) on this point because a researcher‟s assumptions can be declared upfront and made known in a study. For example, I have declared in Chapter One the researcher‟s assumptions about the nature of reality, knowledge and values as far as socially constructed meanings in electricity phenomena are concerned as in this investigation (Guba & Lincoln, 2005; Lichtman, 2010). Also, this study has described vividly how educational action research will be used as methodology to study the phenomenon of DC electricity, taught and learnt through the medium of English to ESL speakers.

3.2.2 Epistemological position

Epistemologically, the study considers constructivism as an active process of knowledge through which consensus is reached by the researcher and the participant teachers by adapting new information into familiar, existing knowledge (Creswell, 2009; Denzin & Lincoln, 2005). Lichtman (2010) suggests that interpretivists and constructivists seek to understand phenomena by interpreting the subjective perceptions of individuals during the construction and reconstruction of reality. In so doing, the values of each individual referred to as axiology have been addressed in the study by acknowledging that findings that I have made are value-laden because my beliefs have been allowed to influence certain parts of the study (Denzin & Lincoln, 2005; Lichtman, 2013). In addition, the values of each participant have been accommodated by reflecting on the importance of the level of flexibility offered to the participants during the research process. The level of involvement of the participants has a bearing on how much freedom they should exercise in the study and how the researcher has planned to protect participants from harm during the investigation (Lichtman, 2010; 2013).

Acknowledging the pluralistic nature of reality highlights the critical role played by my subjectivity in this study (Lichtman, 2010; 2013). My personal experiences, beliefs and expectations have played a central role in the research process whereby my experience as an isiXhosa speaking Natural Sciences teacher has made it easy to share ideas with the teacher component of the research participants. I have also found it easy to relate from the learners‟ point of view when it came to language issues since I am also an isiXhosa-speaking teacher and researcher. The need to disclose my subjective role is an important indication that I have been aware of how my background, interests and points of concerns have affected the study at different cycles of the educational action research (Lichtman, 2013). In brief, self–reflection has created a platform where the information received from the participants was filtered through my own lens as a Grade 9 Natural Sciences teacher and subjected to a multitude of interpretations based on my background as an isiXhosa speaking teacher who has passed high school and teaching diploma in Physical Sciences by rote learning (Lichtman, 2013).

The impetus for my investigation was the recognition of my high pass rates coupled with meaningful understanding of Physical Science which I received when I furthered my studies at degree and postgraduate level. During my studies, I was exposed to analogies as teaching and learning strategies that can improve understanding of abstract concepts. Indeed, it became my concern to investigate if my peer teachers who teach in the same residential area as I do, exposed to learners who come from more or less the same background and have low Natural Sciences pass rates in their schools, use analogies as teaching strategies or use the traditional method of teaching. Of paramount significance in this study is the view that the general understanding and shared meaning of particular electricity concepts have been brought to the fore based on usage and the way of life of participants in their familiar settings (Basit, 2010; Lichtman, 2013). Hence, the initial idea was to get a general understanding of how teachers were teaching in their natural school settings. In addition, teachers were required to choose an effective analogy based on their interpretation of the appropriateness of the analogy to the context of their learner by enquiring whether the constructs used in the analogy are familiar and easily understood by the learners.

Bearing in mind that human bias and the notion of objectivity versus subjectivity are some of the key elements of interpretivism that are criticised by various scholars, I tried to guard against these pitfalls rather than denying their existence (Lichtman, 2010). Therefore, I have been cautious about the notion of bias by taking into consideration the principle of disciplined subjectivity by striving to keep the dynamic tension between my subjective role and that of the participant teachers so that I do not fully belong to either group. Maintaining an insider and outsider role has been important for the validity of this study so disciplined subjectivity created a state of neutrality where the researcher‟s subjectivity has been kept separately from that of the participants, hence being able to maintain an insider stance while taking an outsider stance too (Lichtman, 2010). To achieve this goal, I have used field notes which record interests, beliefs and experiences which may create a bias to the study before tackling each data collection technique.

3.2.3 Ontological position

An essential tenet of social constructivism is based on the ontological position to reality that reveals that there are multiple, subjective, idiosyncratic realities and knowledge is relativistic (Lichtman, 2010). The study regards ontological disposition to reality as a critical factor as it addresses some of the research questions of the study. Hence, this study epitomises the view that there are many realities which influence learning for isiXhosa speaking township learners who come from an environment where daily lives are spent with little exposure to neither electricity nor English except in instances where English is used as a medium of learning and teaching inside the confines of the school classroom. Adherence to this ontological stance is a view which is also consistent with Denzin and Lincoln (2005), as well as Lichtman (2010, 2013), where emphasis is on meaningful learning rather than teaching for the mere recall and recital of knowledge.

Without sounding redundant, the view that nothing is absolute accommodates one of the objectives of this study which seeks to determine how isiXhosa speaking Senior Phase teachers teach simple circuit concepts to their isiXhosa speaking learners in an environment with limited usage of electricity and English language in their daily lives. That is, the role played by one‟s daily life experiences endorses the notion of quotidian human construction which emphasises the importance of common, daily activities experienced by individuals under ordinary circumstances when constructing new knowledge (Montero, 2002). As Montero (2002) elaborates, reality is socially constructed and partly shared by most individuals forming a social group at a given time and this means that there are many realities depending on the character of truth given by a social group over a certain period of time. Hence, I decided to investigate and develop a diagnostic assessment item in the form of a familiar picture consisting of a battery which is used in a torch and a light bulb which is easily seen and used daily in the learners‟ environment without introducing any barriers on learning.

Supporting the view that truth is not absolute, Rudrum (2005) draws our attention to the position of social constructivism where a social semiotic theory of truth has emerged to explain representations in the form of texts and drawings. Advocacy is pronounced on the idea that truth is subject to the constructs of a particular social group which shares certain values and beliefs so that a given picture is a representation of sequence of events which have been used in different ways throughout our lives. The study intends using a picture of a battery connected to a light bulb to check how words or graphics are normally used by members of the same language and culture in a particular community (Rudrum, 2005). The particular learner community in this study is an isiXhosa speaking community which does not have usually have electricity as a normal, daily part of life. Therefore, the study seeks to probe the learners for alternative conceptions in DC circuits by encouraging them to express themselves in drawings and any language which will truly reflect the context of their community.

Consistent with this view, particular emphasis is given to the question of concepts and language use as being intertwined with social practice and people‟s conventional way of life (Rudrum, 2005). Reflecting on my own knowledge of isiXhosa, the nuances of the term "umbane" have been raised earlier in Chapter One of the study as a matter of concern when considering the implications of language and concepts used by ESL learners. "Umbane" is commonly used in isiXhosa homes to refer to prepaid electricity tokens from the municipality. Also, the term is similarly used at school to refer to the topic dealing in electricity such as DC electric circuits. Therefore, language plays a pivotal role in the study as ambiguities indicated in the term "umbane" may influence the development of alternative conceptions in Natural Sciences. Vygotsky (1978, p. 57) captures the importance of language as:

> *Every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level.*

3.3 Action research as methodology

It is 60 years since Kurt Lewin created the phrase action research to describe the process of generating corrective actions by reflecting upon problems in practice. Action research has evolved into different forms to suit the theoretical and practical needs of the participant but the general features of a cyclic process namely problem identification, solution selection, implementation and evaluation of outcomes remain the same (Kemmis & McTaggart, 2005). It is essential to distinguish between the specific type of action research used in the study and other types of research to allow the reader to understand the methodology used and allow the research to be judged accordingly.

3.3.1 Unique characteristics of action research

The many forms of action research share a number of common elements that differentiate it from other types of research. Action research has often been envisioned as a cyclical process in which successive episodes grow ever closer to successful resolution of the problem. These action research cycles are meant to be responsive events that are in practice and frequently change mid-cycle as results dictate the need, that is; if the action does not help alleviate the problem, the action is changed until it does (Kemmis & McTaggart, 2003).

Other key elements of action research are personal engagement and collaboration among the participants. It is important to note that the researcher does not provide a treatment to subjects; rather all parties concerned are considered participants with an equal voice. The goal of action research is to acquire knowledge which has been generated through reflection and discussion with research participants (O‟Brien, 2001).

3.3.2 Classification of action research

The literature describes multiple classifications of action research, each reflecting a different epistemological position and purpose. The work of Habermas has also influenced thinking about action research (McTaggart, 1991). His theory of knowledge-constitutive interests suggests how knowledge is constituted and reflects the way it is subsequently used. For example, knowledge developed through hermeneutic-interpretive strategies is used for practical applications. Based on

Habermas‟s theory of knowledge constitutive interests, three broad types of action research can be identified (McKernan, 1991). Type 1 is scientific-technical and has positivist traits and involves testing a particular intervention within a specified theoretical construct. Type 2 is practical-deliberative and involves collaboration among participants to define, understand and solve a problem. Type 3 is critical-emancipatory and focuses on designing practical and political action to theoretically situate and solve an identified problem.

Cochran-Smith and Lytle (1999) have developed an analytical framework for teacher action research that has two broad categories, namely, empirical and conceptual.

Empirical action research deals directly with the analysis and interpretation of data collected through fieldwork. In conceptual research, teachers use many sources of information to build persuasive essays about educational research, classroom situation and other reflections found in the school situation. Empirical action research can further be demarcated by the type of reflection used in the study, namely teacher journaling, oral inquiries, and classroom or school studies. Through journal writing, teachers privately reflect upon the impact of their instructional practices upon their students. Collaborative group reflection can use oral enquiries where many teachers discuss issues, experiences and meaning related to the outcomes of their own teaching within their own classrooms, while classroom studies can either be individual or collaborative.

The distinguishing feature of classroom action research is that it is conducted by teachers and occurs in school and university classrooms. The emphasis of the research is on practical classroom issues such as building classroom community or how to help a class of children master a specific domain of knowledge. Theories used to guide classroom action research are more likely to be learning theories.

Based on the abovementioned classifications, Rearick and Feldman (1999) developed a framework that considers action research from all three perspectives:

- its theoretical orientation (technical, practical, or emancipatory);
- the purposes for the research (professional, personal, or political);
- the type of reflection involved (autobiographical, collaborative, or communal).

In view of the aforementioned philosophical basis of the study, this study can be classified as a an empirical study located in a practical paradigm using collaborative reflection to solve a problem experienced by a sample of teachers in their science classrooms, namely that of teaching simple electric circuit concepts using contextually appropriate analogies.

3.3.3 Data generation and analysis used in action research

Data collection methods in action research are selected to provide the data necessary to answer the research questions. However, the cyclical nature of action research such as identifying a problem, data collection, action on collected data, re-evaluation of the problem, repeated data collection - often requires multiple forms of data collection techniques within the same project. Cochran-Smith & Lytle (1993) suggested learner generated artefacts such as worked out questions or journal entries, as well as the use of interpretive data analysis methods such as discourse analysis, oral processing, document analysis and reflection journals (Kemmis & McTaggart, 2003) as suitable data sources and analysis techniques.

3.3.4 Quality in action research

Action researchers need to pay particular attention to the conceptualisation of validity in action research.

> "*Without a robust and well-structured approach to validity, educational action research is susceptible to a number of pathologies."* (Newton & Burgess, 2008, p. 27).

Waters-Adams and Nias (2003, p. 293) believe that "the key to the validity of action research undertaken by any participant lies with the kind of approach he or she has adopted, rather than an adherence to specific ways of working". Since validity in qualitative research involves determining the degree to which researchers‟ claims about knowledge corresponds to the reality (or research participants‟ construction of reality) being studied, Cho and Trent (2006) argue for the use of a recursive, process-oriented view of validity as a framework to ensure quality in action research. They further argue that as action research is a process, linking concerns of validity with the purpose of the study will lead to a better understanding of how validity should be differentiated for each purpose (Cho & Trent, 2006).

Cho and Trent‟s (2006) view of validity as a process, necessitates explicit attention to the inclusion of validity considerations throughout the inquiry. This process view moves the concept from an application of „the right criteria at the right time‟ to a process of „thinking out loud‟ about researcher concerns, safeguards, and contradictions continually. Newton and Burgess (2008, p. 19) concur with Cho and Trent by suggesting that rigour in action research can be ensured by "reconceptualizing validity as contingent on the mode of research being used". They propose the validities identified by Anderson and Herr (1999) (cited by Newton & Burgess, 2008), namely outcome validity (the extent to which the outcomes of the research match the intended purposes of the research), process validity (the efficacy of the research approach in addressing the research problem), democratic validity (the extent to which research is done in collaboration with all parties who have a stake in the problem under investigation), catalytic (the ability of the research process to transform the participants, deepen the understanding of the participants, and motivate participants to further social action) and dialogical validity (the participation of the researcher in critical and reflective dialogue with other practitioner researchers), as particularly suitable for this purpose.

In Table 3.1 Newton and Burgess (2008) illustrate how the three modes of action research rely on different primary and secondary validities to assess their knowledge claims.

Table 3.1 Action research modes and corresponding validities (Newton & Burgess, 2008, adapted from Anderson & Herr, 1999).

Action Research Mode	**Primary Validity**	**Secondary Validity**	
Knowledge generating	Outcome validity	Democratic validity	*Dialogic Validity*
	Process validity	Catalytic validity	
Practical (improvement of practice)	Catalytic validity	Process validity	
	Outcome validity	Democratic validity	
Emancipatory	Democratic validity	Process validity	
	Catalytic validity	Outcome validity	

They argue that the manner in which knowledge claims are assessed is dependent on the primary goals of the action research project, its purposes and epistemologies. Primary validities are not sufficient to ensure quality in action research. They argue that secondary validities ensure that the research project falls within the domain of educational action research, ensuring the project share the epistemological and ontological features of action research.

3.3.5 Rationale for selecting classroom action research methodology for this study

Based on my research questions, my research methodology will be a qualitative action research study primarily because of the flexibility of such a design and the adherence to naturalism as an epistemological stance (Babbie, 2004; Lincoln & Guba, 1985; Struwig & Stead, 2001). As qualitative action research does not emphasise professional knowledge at the expense of local knowledge, the qualitative approach is relevant to the intricate, context and culture of isiXhosa speaking community. Further, a qualitative approach accommodates the ontological position of plural meanings to reality where reality is not judged according to absolute rules (Denzin & Lincoln, 2005; Lincoln & Guba, 1985). In essence, the qualitative approach pays particular attention to the context of individuals because individuals form part of social, traditional or historical reality. A qualitative approach further creates the capacity for the emergence of thick descriptions based on the context of the participants (Creswell, 2009; Denzin & Lincoln, 2005; Stringer, 2004).

Interestingly, action research puts emphasis on this view by highlighting the idea that action is linked closely to the context of the participants (Denzin & Lincoln, 2005; Lichtman, 2010). Thus, the choice of methodology for this study has been informed amongst other factors, by whether I as a researcher have been fully involved in data collection as the „I" element such that my background has been allowed to a certain extent to shape the phenomenon under study during the various cycles that have been designed (Creswell; 2009). Importance has been ascribed to the view that concept understanding consists of plural meanings which may be aligned to the attitudes that the participants have towards the phenomenon under study, in this instance; the concepts in a direct current electricity circuit.

Action research firstly addressed my research objectives by recognising the important role played by "co-generative inquiry"" which has been developed by me as the researcher and knowledgeable local stakeholders such as the teacher-participants and professional university researchers who took part as described in the research design section of the study (Denzin & Lincoln, 2005, p. 54). High regard is given to the need for PD of teachers where close co-operation has been built between Nelson Mandela Metropolitan University‟s experienced science researchers and teachers involved in the study.

In essence, qualitative approach pays particular attention to the context of individuals because individuals form part of social, traditional or historical reality. Therefore, the view that social reality is neither static nor universally true will be highly considered in the study because the experiences and viewpoints of the individuals would be the prime focus of the study (Basit, 2010). Hence, by communicating the value of context-centred knowledge, the flexible, recursive and cyclic nature of educational action research addresses my research objectives by recognising the importance of the role played by the social and cultural aspects of the participants and the manner in which empirical data was collected.

3.4 Research Design

The selection of educational action research as methodology for the study also informed my **research design** (Denzin & Lincoln, 2005; Lichtman, 2013). A feature of a constructivist paradigm is an emerging research design in which the researcher is closely engaged with the subjects of the study (Lichtman, 2013). My research design is based on the interaction between my philosophical background, strategies of inquiry, research sub-questions and specific methods used in data collection and data analysis (Denzin & Lincoln, 2005; Zuber-Skerritt, 1992).

3.4.1 Setting and sampling

The research was conducted in poorly resourced and poorly performing schools in a township setting in Port Elizabeth. The particular two schools were conveniently selected as they are two neighbouring underperforming secondary schools in Port Elizabeth. The schools were poorly resourced as shown by the state of the schools‟ buildings, non-availability of electricity in the classrooms and lack of science equipment. The schools‟ geographical proximity was considered as both schools were studied in their natural settings and was closer to my own school. This convenient selection of the schools within the framework of the criteria set out for the study (poorly resourced and poorly performing township schools) are in line with the naturalistic nature of the study (Creswell, 2009; Denzin & Lincoln, 2005).

Also, the two participating teachers and their associated classes were conveniently selected because of their willingness to participate in the study. The two teachers were experienced and professionally qualified teachers. One had a Bachelor of Education degree in Mathematics and Natural Sciences (Senior Phase) and the other teacher had a Bachelor of Arts in Education in Geography and Psychology. Also, the teachers were selected on the basis of being the current Natural Sciences teachers in their respective schools in the year of inception of the study.

The participating learners and teachers from both schools were isiXhosa Home language speakers while the language of instruction and learning at the schools were English. One Grade 8 class was selected per school. The number of participants comprised two Grade 8 science teachers with in total 26 boys and 54 girls, making a total of 80 learners; between the ages of 14 and 17 years.

3.4.2 Impact of Researcher's Identity on the study

The qualitative approach of the study accommodated my emic, insider and teacher viewpoints as I conducted the research while I was also a teacher in one of the schools participating in the study (Denzin & Lincoln, 2005). Based on the qualitative nature of the study, it was important that my role as the researcher should take into account the natural language, beliefs, culture and manner of teaching and learning of the teachers and learners whose home language was not English (Creswell, 2009; Denzin & Lincoln, 2005).

Central to action research, is the idea that teachers possess „insider‟ knowledge into the practice under investigation, which is essential to transform and improve education practice (Manfra, 2009; O‟Brien, 2001). I possess insider knowledge based on my position as Grade 8 and 9 Natural Sciences teacher in one of the selected schools for the past 20 years. I will be the main researcher in the study and will collect data related to the research questions and initiate planned opportunities that will allow the participating teachers to think and reflect on their teaching practice with regard to the teaching of simple circuit concepts (Manfra, 2009; O‟Brien, 2001).

However, I did not actively teach any lessons during the study. My role was limited to data collection and analysis of the teaching and learning situation as performed by the participating teachers and learners (Creswell, 2009; Denzin & Lincoln, 2005).

The choice of an interpretive paradigm involved interpretation of the teachers‟ actions before, during and after the presentation of the lessons on DC electric circuits. My identity was particularly helpful during the interpretation of the teachers‟ and learners‟ actions if viewed against the backdrop of my own experiences as an isiXhosa science student and science teacher who has learnt science through the medium of English and was raised in a similar community as the one in which the study is located.

3.4.3 Research cycles

Using the recursive nature of qualitative educational action research (Schmuck, 2006; Stringer, 2004), the study was conceptualised around three distinctive cycles, based on the sub-questions formulated in Chapter One, namely the identification of the problem, selecting a solution, implementing it, and then evaluating the solution‟s effectiveness in a continuous spiral of planning, action, and fact finding (see Figure 3.1 of the study).

Cycle One consisted of a two-fold problem identification phase focussing on teachers and learners as essential components of educational action research. The first part sought to investigate the teachers‟ current style of teaching to find out if analogies had been used in teaching the electricity section of the science curriculum. The second aspect of problem identification focused on the learners to find out if they had any alternative conceptions in their understanding of DC electric circuits.

Cycle Two dealt with the selection of a solution to the problems identified in the first cycle and mainly focused on the development of an intervention strategy to enhance the pedagogical content knowledge of the teachers on the use of analogies in teaching science. Cycle Three involved the implementation of the proposed solution developed in the second cycle by the two teachers in their classrooms, reflecting on the solution‟s effectiveness.

In keeping with the nature of qualitative educational action research, each step depicted in Figure 3.1 was preceded by problem identification; then a plan of action was made followed by implementation of the selected plan and a period of reflection where participants shared their views (Pine, 2009; Stringer, 2004).

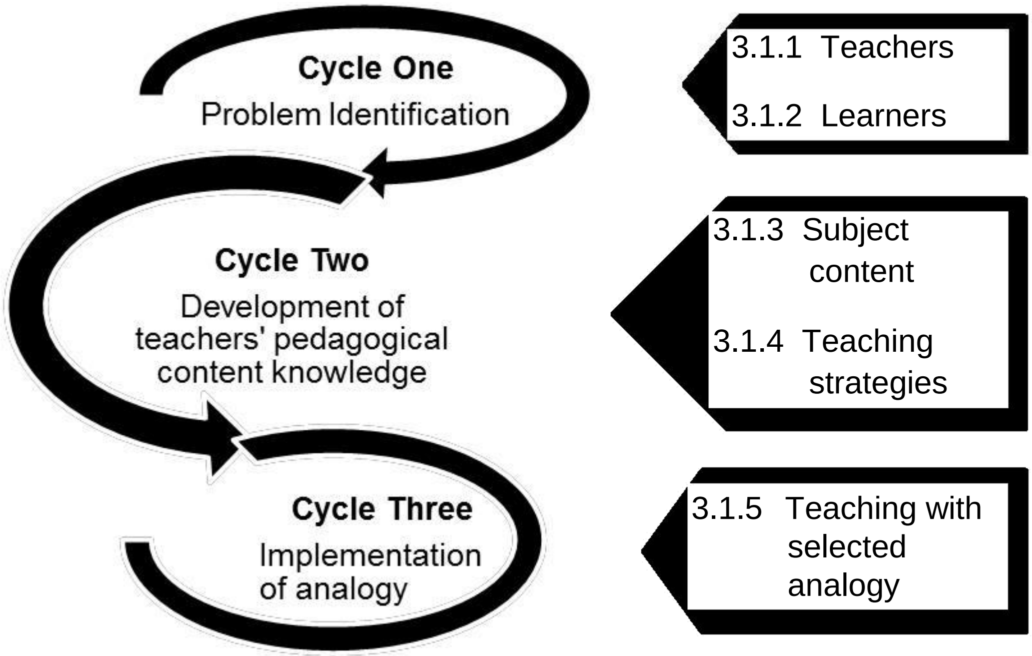

Figure 3.1: Summary of the three cycles used in the education action research study

3.4.4 Data generation and analysis during each cycle

As a result of the iterative nature of the research design, the strategies used to generate and analyse the data collected were distinctively different for each of the cycles. Each cycle will be reported on separately in sections 3.5 to 3.7.

3.5 Cycle One – Problem Identification phase

Cycle One consisted of a two-fold problem identification phase. The first part sought to investigate whether the participating teachers made use of analogies in teaching DC electric circuit concepts in Grade 8, and if they did make use of analogies, to determine what type of analogies they used (research sub-question 1). This knowledge would then be used to determine whether the analogies they used were contextually suited to the learners that formed the sample of the study. The second phase of Cycle One focused on identifying the conceptual model held by the learners prior to the instruction of the teachers, and in particular which mental model learners had about the movement of electric current in closed direct current circuits. This knowledge will be compared to the teaching strategies used by the teachers.

3.5.1 Teacher Problem Identification phase in Cycle One

The first objective of the study was to determine if analogies were used by the teachers in their teaching of simple electric circuit concepts. In essence, what was important at the onset of the study was to establish the type of analogies used by the teachers and to determine if the analogies they used were familiar to the background of the learners in their classes and whether the analogies had been chosen from the pool of internationally accepted science-teaching analogies.

The data were collected by means of semi-structured interviews because "interviewing allows [researchers] to put behaviour in context and provides access to understanding their action" (Seidman, 1998, p. 4) and are as such suited for the qualitative nature of the study. The interview protocol (see appendix C) was linked to the first research question (Creswell, 2009; Kvale, 1996; McNamara, 2009) in order to find connecting threads between the experiences of the teachers in terms of their teaching of simple electrical concepts, the learning of their learners and their own content knowledge (Seidman, 1998). I prepared an interview protocol (see appendix C) which had the same wording of questions so that I could sift through the narrative responses of the participants in order to get an overall idea and make an easier comparison on all interview responses (Gall, Gall & Borg, 2003; McNamara, 2009; Turner, 2010). The data were analysed immediately after the interviews were conducted to ensure that the subjective responses of the participants were not lost before doing further analysis (Lichtman, 2013; McNamara, 2009; Turner, 2010).

Moreover, the in-depth nature of standard open-ended interviews accommodated the aspect of elaborate, personal and rich detail which is central to qualitative research. Conveniently, the in-depth nature of standardised open-ended interviews gave me freedom to ask probing questions as a follow up to responses which were not clear.

The following preparations suggested by McNamara (2009) were taken to ensure the interviews were successfully conducted:

- Agreeing with the participants in the choice of a classroom for the interviews where there would be less distraction;
- Describing the objectives of the interview in advance;
- Telling the participants how many interviews would take place and how long the interviews would be;
- Reminding the participants about the confidentiality forms that were signed at the onset of the study and enquiring if there were any clarifications to be made;
- Trying to create a comfortable environment by explaining how the interview would take place and ensuring that they knew where to get hold of me when necessary;
- Ensuring that the audio recording instrument was working efficiently.

Midway through the interview, the second teacher (T2) requested the audio-recording of the interview to be stopped. Although (T2) did not finish the whole recorded interview session, the partially recorded clip has been transcribed and kept for record purposes as it formed part of valuable data collected during Cycle One. Field notes were taken of the remainder of the interview with the second teacher. The informal conversation interviews were unplanned but they were used to deal with the unexpected circumstances that were experienced during the study, such as the refusal by teacher two to continue with audio-recording of the interview in Cycle One (McNamara, 2009; Turner, 2010).

The initial plan was to follow-up the in-depth interview with the teachers completing the same diagnostic assessment questions that were planned to assess the learners‟ understanding of the electric flow in a circuit. The idea of the diagnostic assessment would have been to establish whether the teachers had any alternative conceptions about concepts in simple electric circuit. However, both teachers refused to carry on with the written task; stating that they felt belittled to write the same diagnostic test as the learners. They also indicated that they felt uncertain about their content knowledge regarding simple electrical circuits. Although I went to a great extent to explain that the assessment items would not have their names and would not have any negative influence in terms of their relationship with me and their level of science conceptual understanding, the teachers politely refused but offered to willingly give the task to the learners. I was bound by the ethical principle of volunteered participation not to push any more.

Wary of the contrasting views raised by Creswell (2007) that informal conversation interviews have inconsistent questions which make coding of data difficult, I conceded with McNamara (2009) who argues that the flexibility and spontaneity of informal conversational interviews is valuable in dealing with surprising situations during an investigation. Hence, while faced with an impasse when both teachers refused to write the task, I was rescued by informal conversational interviews as they formed part of my “observation fieldwork” (Gall et al., 2003, p. 239). To assist with more data collection, classroom observations of the teachers‟ verbal and non-verbal behaviour were recorded in the field notebook and kept as part of data collection. The conversational interviews were unstructured because questions were raised spontaneously as I was trying to understand the unexpected encounters and trying to interact with the behaviour, attitudes and ideas of the teachers (Gall et al., 2003; McNamara, 2009; Turner, 2010).

3.5.2 Data analysis and data interpretation of teacher problem identification phase in Cycle One

My relationship with the participants in this study allowed me to be reflexive and participate in our shared culture as previously stated that I am also from the same isiXhosa culture as the learner and teacher participants. Fereday and Muir-Cochrane

(2008, p. 82), cited Rice and Ezzy who argue that common themes can be deducted by “careful reading and re-reading of data”. All similar data have been combined and catalogued into sub-themes; for instance, themes of conversation, meanings, common folk-saying. To identify knowledge of analogies I put common themes aside as in this example:

> “I use examples to simplify problems.”
>
> “I use examples from textbooks or scientific analogies or cartoons.”

Firstly, thematic data analysis enabled the researcher to get an idea of whether the teacher knew what analogies by looking for key words and non-verbal cues that revealed a common theme (Lichtman, 2010; 2013). In line with the qualitative nature of the study, I transcribed the digitally recorded formal and informal interviews verbatim and changed the hand-written classroom observations by changing audio and hand-written data into clear and legible electronic text. The transcribed data, as well as the field notes were used to identify patterns from all the fragmented ideas of the participants (Lichtman, 2010; 2013*).* In pursuit of accuracy, I transcribed the interviews and verified the content with the teachers (member-checking). During the process of transcription, I started the analytical process when I started to familiarise myself with the data in order to make it intelligible to me as a researcher and also to another individual who would be reading the document (Holliday, 2002).

What has been significant was that themes have brought fragmented pieces of ideas into a coherent whole of collective ideas. The postulate of subjective interpretation accommodates the participants‟ subjective point of view and acknowledges the context within which the phenomenon was studied (Basit, 2010; Lichtman, 2010). For example, the theme on analogies on teacher problem identification in Cycle One has emerged from data analysis of informal conversation interview where T2 clearly indicated that „*I do not know analogies*‟. Then, a sub-theme on analogy knowledge has been formed where all similar data on „‟do not know analogies‟‟ can be grouped together.

Table 3.2 presents a summary of the phrases which were coded to get a broad theme with subthemes, for example: the type of teaching strategy has sub-themes such as constructivist method and textbook method. Other broad themes like code-switching and level of subject content knowledge were also compiled in this format. Data was repeatedly read and sorted out to get a category with similar phrases or signs of non-verbal behaviour (Boyatzis, 1998; McNamara, 2009). Also, a category consisting of different words and non-verbal behaviour was put separately to identify the type of teaching strategy used by the teachers.

Table 3.2: Data from specific moments during data analysis for identifying theme on type of teaching strategy, (Boyatzis, 1998)

Teacher One (T1) or Teacher Two (T2)	
Constructivist informed teaching (analogy use)	**Traditional, textbook method**
Use of pictures to link prior knowledge with new knowledge	I tell the kids I use the textbook
Use of familiar examples from learners‟ background linked to lesson in DC electric circuits	I use the book for information I ask them, they tell me
Use of stories connected to parts of DC electric circuit	I use the textbook to make them pass exams

In line with the social constructivist and interpretivistic nature of the study, thematic data analysis has been supported and interpreted by using transcribed excerpts from informal conversation interviews, audio recorded standard open interviews and notes of non-verbal body language (Babbie & Mouton, 2001; Creswell, 2009; McNamara, 2009).

Sifting, sorting and categorising data was not an easy task because the answers which I needed to address the research question of the study were hidden behind the thick descriptions of the participants, for example T1 gave a lengthy explanation and explained that:

"*I have to go back to static electricity so that they can know the difference between static electricity and I‟ll tell them about some of them things that they can use ahm…ahm...in order for them to know what is electric current and how electric current is working."*

T2 stated that „*I **use the textbook** and **tell** the kids that this symbol represents a cell …"* Therefore, all similar words like „*tell the kids*‟; „*I‟ll tell them*‟ or „*I use the textbook*‟ were grouped together to represent the textbook subtheme, contrasted against the constructivist methods.

Finally, understanding of subject content knowledge has been examined by determining the knowledge gap by searching for evidence of alternative conceptions in teachers‟ concept understanding in simple circuits (Duschl et al, 2007; Glynn, 2008; Shipstone, 1985). The knowledge gap has been identified by analysing teacher alternative conceptions where the use of science concepts which are inconsistent with scientific use during interviews and instruction would indicate the existence of alternative conceptions. In order to increase the reliability of the study, I developed a table to put the coded phrases for the type of teaching strategy that emerged from the data collected from each teacher (Boyatzis, 1998). The table was built from specific moments that were recorded during data analysis that emerged as being significant (Fereday & Muir-Cochrane, 2008). For example, T1‟s response to a question enquiring about the type of teaching strategy she used to teach direct current electricity circuits was as follows:

"*… I tell them about some of the things that they can use.*"

T2‟s response to the same question was similar:

"*…so I use the textbook and tell the kids that this symbol."*

These responses were coded as the textbook method as a response to the question on the type of teaching strategy.

3.5.3 Learner Problem Identification Phase in Cycle One

The second phase of Cycle One concentrated on the learners" perspectives on how the electric current flows in a closed series circuit. The original plan was to take stock of the leaners" understanding by asking them to answer diagnostic questions related to various conceptual models around current flow in simple DC electric circuits. The aim was to determine whether by means of a pre- and post-test strategy whether the analogy chosen by the teachers to explain the simple DC concepts addressed the conceptual problems identified as being present in the participating group of learners. However, unexpected responses from the learners (see the discussion of the data collection using pre-test diagnostic items in section 3.5.3.1) necessitated adapting my plan and designing a modified assessment tool to be used as data collection tool in order for me to continue with the study. Hence, two types of data collection tools were used to determine the conceptual problems experienced by the participating group of learners (see appendix D for the first diagnostic test and appendix E for the second diagnostic test).

The first diagnostic assessment items consisted of four multiple-choice questions consisting of circuit diagrams with universally accepted symbols for components of simple direct current electric circuits (appendix D). The second diagnostic test administered to the participating learners consisted of a colourful photographic picture of a battery connected with two connecting wires to a light bulb (appendix E). More emphasis was placed on requiring learners to draw their answers than on their writing skills in responding to the question. Each of these two tests, as well as the decisions taken to end up with the second version of the diagnostic test, is described in more detail in the sections to follow.

3.5.3.1 The first diagnostic pre-test using universally accepted scientific symbols

A data collection pre-test (see appendix D) was developed to determine the alternative conceptions in simple circuits held by the participating learners. The learners would have already covered the content required to complete the pre-test in Grade 7 as per the requirements of the curriculum of Natural Sciences in South

Africa (Revised National Curriculum Statement Grades R - 9, Government Gazette No. 23406 of 31 May 2002) under the knowledge strand of „Energy and Change‟ (Revised National Curriculum Statement Grades R-9, 2002, p. 13). Therefore, the symbols should have been familiar knowledge to the learners as it formed part of the assessment standards for Natural Sciences from Grade 7 to Grade 8.

The actual items used in the diagnostic assessment tasks have been selected from items designed by the University of York Science Education Group (UYSEG) 2002 at http://www.york.ac.uk.depts/educ/projs/electricity. The rationale behind using the four questions was based on the general idea that the symbolic language used consisted of universal and international symbolic language used in many science books, making the choice of a solution easier as learners should have easily recognised the symbols and what they represent (Asoko, 2002, Heywood & Parker; 1997; Kibble, 2002). Secondly, the medium of teaching and learning in the selected schools was English therefore I did not expect any major challenges from the learners as they were required to select the correct response from a list of given choices. Thirdly, less writing was required as the learners were required to only choose the correct response by making a tick in the box next to the correct answer given in the multiple choice questions.

The test consisted of four items dealing with the size of the electric current, use of the ammeter as a current measuring instrument and direction of the electric current. Each of the four selected items was directed at answering the research question and sub-questions of the study which target learner understanding of simple DC concepts, for example:

- Question one investigated the size of the electric current when two identical light bulbs were connected in series with one cell;
- Question two investigated the size of the electric current at two points (A and B) with one cell and one light bulb connected in between the two points (A and B);
- Question three examined the size of the electric current when measured by two ammeters in a circuit with one cell. The first ammeter was placed before the

electric current entered the resistor (R) and the second ammeter was placed after the electric current has moved out of the resistor;

- Question four investigated size and direction of the electric current using a pictorial representation of a battery connected to a light bulb.

The questions were administered by the teachers in their individual schools. In one school, the teacher proceeded by asking the learners whether they understood the language in which the questions in the assessment have been asked. Only one learner responded verbally and clearly in intelligible English to indicate that she did not understand. The teacher asked questions in English and intermittently in isiXhosa when she observed that the learners were not answering the diagnostic questions. I carefully noted the lesson proceedings in writing in the field notebook. In the second school, learners simply looked at the teacher and a few shook their heads. Figure 3.2 shows an example of one of the questions of the diagnostic item which learners refused to respond to, saying *"inzima"* in isiXhosa (it is difficult).

As a result**,** not even a single learner from both schools attempted to answer the diagnostic assessment task on universal circuit diagram symbols; hence there are no results on the task. My initial expectation was that learners would willingly write the task and I was therefore caught by surprise at the lack of engagement by the learners from the first school. When learners from the second school also refused, I felt stressed as I felt that I was losing the goals of my study. As the lessons were presented on the same day in the different schools, I could not adapt my data collection technique to include tape recording of the classroom observation.

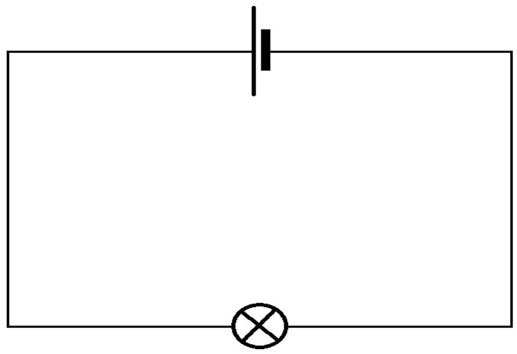

Figure 3.2: First diagnostic item - Universal symbolic representations of a circuit diagram (adapted by the University Of York Science Education Group 2002 at http://www.york.ac.uk.depts/educ/projs/electricity)

Upon reflection with the teachers and also in an effort to continue with the study, I decided to adapt the pre-test to include an item that would be familiar to the learners‟ everyday life, and as such allow the research to continue. The adapted diagnostic test will be discussed in the next section.

3.5.3.2 The second diagnostic pre- test

The search for another diagnostic tool was time-consuming and stressful. I engaged the teachers in an informal conversation to find a way to arouse the interest of the learners and get them to engage with the diagnostic test. Based on the informal conversations with the teachers, it was decided to develop an item which was interesting and colourful yet familiar to the every-day life of the learners. Another factor that needed consideration was the amount of reading that was required from the learners, as well as the use of English to answer the conceptual questions. I decided to develop an assessment item which would minimise the use of reading and writing in English but allow the use of drawings and the use of isiXhosa vernacular by the learners when explaining their thinking in the blank spaces provided in the diagnostic item. I reduced the four-question test to a one item test to start off with.

I chose an item which I felt had a more familiar drawing of the circuit diagram (see Figure 3.3). I selected six Grade 8 learners from my own school that are not part of the participating cohort of learners and piloted the new diagnostic item. I administered the test and afterwards had an informal discussion with them to determine their perceptions of the newly selected test item.

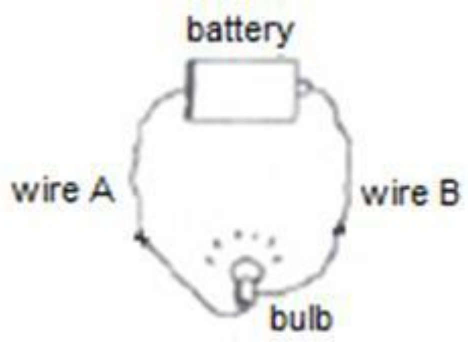

Figure 3.3: An interim circuit diagram considered for possible inclusion in the diagnostic test

Their responses to the representation of the circuit were that it looks like a test and they do not like to do a test since they normally do not achieve in tests. The drawing also looked very similar to drawings found in their textbook and they do not understand the textbook. They expressed a need to have something colourful and interesting instead of the same boring stuff that is always in the textbook. Based on the responses of the four learners about the representation of the circuit, I decided to change the item again to provide the study with the best possible chance of collecting the data needed from the learners.

I finally decided on the use of a photograph of a familiar electrical circuit consisting of a battery which is normally found in a torch, two connecting wires and a light bulb on a bright blue background (see Figure 3.4). I had to ensure that the appealing aesthetic features of the image portrayed the scientific ideas that the study undertook to investigate to ensure that my research sub-questions were still addressed by the new task and the study was valid. The importance of the test item was that the questions allowed for a choice of language and allowed for the development of the learners‟ own views because learners were required to *„explain in own words‟* as stated in question (b) and (c) (see appendix E for the final question).

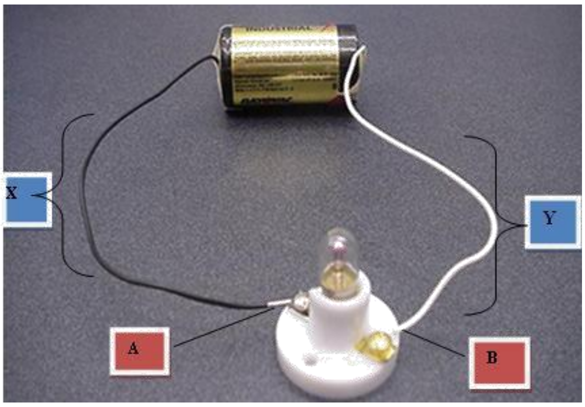

Figure 3.4: The final representation of the circuit included in the diagnostic test

The teachers administered the second version of the diagnostic test (appendix E) to the learners in both schools during the respective scheduled Natural Sciences lessons. After the completion of the diagnostic item by the learners two learners from each class were invited to participate in informal interviews to determine their responses to the diagnostic test (Kvale, 1996). The interviews were digitally recorded and transcribed (see appendix F). The field notes made during the classroom observations were typed to serve as reliable evidence of the non-verbal engagement of the learners with the diagnostic test.

3.5.4 Data analysis and interpretation of the second diagnostic test

The results of the second diagnostic pre-test administered to the learners were thematically analysed. The design of the task sought to minimise the use of English usage and writing and encouraged more symbolic writing in the form of drawings. In so doing, the learners were required to draw straight lines of which the size was a representation of the size of the electric current in the circuit on both sides of the light bulb (see appendix E). The learners were also asked to explain the answers to the following two conceptual questions:

- Do you think that the electric current is equal or unequal at different places in a closed circuit? Explain your answer in the language of your choice; and

- Do you think that the electric current is moving in the same direction or at different directions all around the circuit? Give a reason for your answer in any language that you feel comfortable with.

The coding of the learners" drawings in the pictorial representation was done qualitatively as follows. A drawing of *equal straight lines* on the sides of points A and B of the diagnostic item in appendix E would be coded as the *scientific* model where the current is equal on both sides of the bulb. Two *unequal straight lines* illustrating the current on both sides of the bulb to be unequal would be coded as the *consumption model*, irrespective of which of the two sides are the smallest or the largest. Arrows at the tip of the straight lines would indicate the direction of the electric current before entering the resistor at (A) and leaving at point (B). Arrows pointing in the same direction, from one side of battery terminal and completing the cycle would code for the *scientific model*. Arrows pointing in opposite directions or drawn from both terminals of the battery and pointing at the light bulb, would code for the *clashing model* which forms part of the consumer model. Similarly, straight lines with arrows pointing in opposite directions would indicate the clashing currents model.

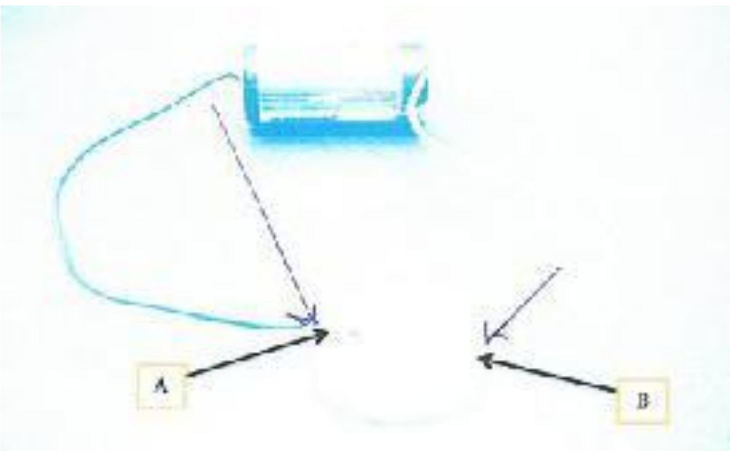

Figure 3.5: The learner's response coded as consumption model and clashing currents model

Figure 3.4 illustrates a response that was coded for the consumption model based on the length of the two arrows begin not equal, as well as the clashing model since the arrows pointed in opposite directions (both pointing to the bulb). The response by this learner illustrates that the learner believed the amount of current in the one section of the circuit is not the same as the amount of current in the other section, as well as that the current flows from the battery to the bulb.

Using a technique described by Guba and Lincoln (2005), I compiled a score sheet with two columns: a blue column and a red column. I compiled a score sheet using coloured marking pens to mark the learners‟ individual responses either with a blue or a red mark and tally them under a column depending on the data (McNamara, 2009). All those drawings where the lines representing the size of the current were equal were marked in red and recorded under the red column. The blue column was used for the „unequal lines‟. Arrows pointing in the same direction were also grouped together under the red column, while arrows „facing towards each other‟ or „the absence of arrows on a line‟ were put under the blue column (Guba & Lincoln, 2005). Each of the learners‟ responses (n = 78) were manually inspected and tallied under either one of the columns, based on the length of the lines they had drawn and the direction of the current flow as represented by the arrow heads on the drawings (McNamara, 2009). See Table 4.2 for the actual data.

The written explanations to the conceptual questions were thematically coded. A written explanation in any language which suggested that the *light bulb used the current,* or *current is less at B than at A,* or the *battery supplies current so it is less at point B*, would be code for the *consumption model* or source-consumer model.

Specific moments which were indicators for a particular theme emerged during the interviews amongst the learners. For example, the response of one of the learners to the question about the size of the electric current at A in the pre-test photograph diagnostic assessment item; the response was as follows:

> *"Umbane umkhulu before ufike kwi light bulb and then ufike kwi light bulb and then la bulb iyawutsala iwusebenzise uphuma umncinci ke ngoku*"

(VERBATIM English translation):

> *"The electricity/ electric current is bigger before it enters the light and the light bulb draws some electricity and uses it and then less electricity leaves out of the bulb".*

Noting the learner‟s response in the field notebook, the presence of the words „*electric current is bigger and becomes less on reaching light bulb*‟ was coded as the consumption model. Data interpretation also revealed the challenge posed by the learners‟ use of isiXhosa language due to the ambiguity of the term „umbane‟.

In the learner‟s isiXhosa exposition, the term „*umbane umkhulu*‟ which in English means *„big electricity (size)*‟" can refer to two issues:

- The correct term in isiXhosa language for „umbane‟ which is an incorrect scientific term in English „electricity‟ as it cannot be defined (explained before);
- The term „electric current‟ in English which does not have not have a direct term in isiXhosa.

Regardless of the dual meaning of the term „umbane‟, the moment the learner indicated „size is bigger at entry point A‟; that specific phrase was coded for the consumption model of source-consumer model.

3.6 Data collection during Cycle Two – Professional Development Intervention

Based on the insight gained during the first cycle of the research and true to the cyclic nature of educational action research (Summers et al., 1997; Lichtman, 2013), a PDI was designed for the participating teachers. The second cycle of the research aimed at enabling the participating teachers to make an informed choice on a contextually appropriate analogy to be used in their classes, followed by the actual selection of the appropriate analogy and the development of a lesson plan for the implementation of the chosen analogy in the teaching of simple electrical circuits.

The professional development consisted of a total of five hours" tuition on two consecutive afternoons, followed by a one-hour session of teacher reflection after the lesson on analogies. The duration of the first session was two hours. The two teachers did not simultaneously attend the first session that focused on content knowledge as one of the teachers had to attend a Life Orientation workshop. However, this teacher (T2) was accommodated by the facilitator by offering her another individual session on another day.

The workshop was designed to develop the subject content knowledge in simple circuits of the teachers by means of a practical, hands-on demonstration by both the facilitator and the teacher. A demonstration lesson on how analogies were used in teaching simple circuits was presented during the next three hour session at the same university. The facilitator presented a practical demonstration of the selected analogy used in conjunction with a lesson on simple circuits. The teachers were given informal opportunities to reflect on the benefit of workshop and their perceived ability to choose and implement analogies in the teaching of simple electrical concepts. The teachers" reflections were recorded as field notes in the field notebook. Observations and informal conversation interviews were made of the teachers" reflections and participation during the professional development workshops and also recorded as field notes.

During the last professional development session a lesson planning meeting was held where both participating teachers and the researcher collaboratively planned a lesson for the implementation of the chosen analogy. The planning meeting was followed by informal interviews with the two participant teachers to elicit the reasons behind their decisions. The data was recorded as field notes.

3.7 Data collection during Cycle Three - Implementation of the selected contextually appropriate analogy

The third cycle of the study involved the actual implementation of the selected analogy by the participating teachers. The implementation of the analogy in the two participating classes by T1 was digitally recorded for later transcription. The researcher attended the two lessons and recorded observed verbal and non-verbal classroom behaviour of both the teacher and the learners.

Since the data collection spanned over two years (from the first to the third cycle), the learners have progressed from Grade 8 to Grade 9. The same cohort of learners that completed the pre-test completed the post-test and formed part of the learners who were interviewed. A sample of learners was interviewed after they completed the post-test to determine whether their original alternative conceptions have changed after the implementation of the selected analogy. Data was analysed in order to elicit themes from the fragmented pieces of information (Lichtman, 2013).

3.8 Trustworthiness and authenticity of research findings

One of the notions that contributes to trustworthiness in a qualitative approach is that of reliability (Pine, 2009). Reliability is the ability to act consistently, honestly, openly and carry on with accurate collection and analysis of data neutrally (Babbie, 2001; Sagor, 2005; Pine, 2009). To ensure trustworthiness and authenticity in the study, the following measures were put in place:

- **Member checking.** The transcriptions of the interviews were verified by the two teachers involved in this study (Babbie, 2001; Sagor, 2005; Pine, 2009).

- **Authentic research findings.** Denzin and Lincoln (2005) define validity as the establishment of authentic research findings to ensure that the researcher can make a legitimate claim based on them. To ensure legitimacy of this study, I strived for a balanced interpretation of findings by ensuring that the views of other respondents have not been omitted. Hence, views that do not support my research objectives were also included and interpreted in the study (Denzin & Lincoln, 2005).

- **Prolonged engagement.** A further measure that ensured the trustworthiness and authenticity of the research findings is prolonged engagement. The study took place over a period of three years to gain an authentic view of the teaching practices of the teachers and the impact thereof on the learning of their learners (Cochran-Smith & Lytle, 1993).

- **Establishment of credibility.** Techniques for establishing credibility include referential adequacy, peer debriefing, prolonged engagement, audit trail and member checking (Lincoln & Guba, 1985). Referential adequacy will be implemented by keeping evidence (data collection and data analysis) in the form of audio - tapes of interviews from the learners and the teachers, transcripts of validation of the analogy by the physics expert, learners‟ drawings and pre-test in Cycle One, the teachers‟ record book with the learners‟ assessment tasks before and after implementation of the analogy and the teachers‟ workbook with lesson plans containing the culturally-based analogy. In order to enhance credibility of the study, translations from isiXhosa to English were done by a Head of Department for isiXhosa to ensure that the correct translation were correct reflections of the learners‟ original ideas.

Due to the qualitative nature of the study there is no claim for transferability or applicability in other situations and no generalisations will be made (Denzin & Lincoln, 2005). Hence, the findings of the study would not be extended to any other setting as the nature of the sample taken was small, suitable to the desired rich and thick descriptions of qualitative approach (Creswell, 2009).

3.9 Ethical considerations

Ethical considerations in qualitative action research include my moral relationship to the participants (Schmuck, 2006). It was my moral obligation to treat the participants with respect and not view them as mere research subjects. Permission to undertake this research was requested and received in writing from the Provincial Department of Education‟s district office in Port Elizabeth (see appendix A). Permission gave me authorisation to conduct research in the selected schools (Babbie, 2004; Stringer, 2004). Equally, permission was also requested and received in writing from the ethics committee of NMMU before the research was undertaken to ensure that the envisaged study fulfils the ethical considerations set down by the university‟s research section. I undertook to maintain confidentiality at all times by keeping the names of the schools and individuals involved in the study anonymous (Stringer, 2004).

3.10 Chapter summary

This chapter (Chapter Three) explained the methodology utilized in the present study. Information pertaining to the participants, context, research design, data sources, data analysis, trustworthiness and limitations were discussed. The following three chapters will discuss the findings, which both answered and challenged the research questions. The results have been presented in the same sequence in which the three cycles of the study has been described in this chapter, namely:

Chapter Four (Cycle One) focuses firstly on the teacher component by identifying three central issues responding to the objectives of the study. The second aspect of Cycle One deals with the learners‟ conceptual development by identifying and interpreting types of Source-Consumer models evident in the collected data.

Chapter Five (Cycle Two) gives an account of the teachers‟ professional development where a PDI was conducted in simple circuits and use of analogies in a nearby university in order to address the weaknesses identified in Cycle One. After lesson presentation, the teachers actively engaged in the demonstration of the analogy where they evaluated and selected an analogy viewed as appropriate to the context of the learners and teachers as well.

Chapter Six (Cycle Three) details the implementation stage where the selected contextually appropriate analogy is used by the teachers during lesson presentation in the respective participating schools, its usefulness as an analogy that is contextually suited to the particular group of learners, and the effectiveness of the analogy in addressing the conceptual understanding of the learners.

Chapter 4
Findings of Cycle One

4.1 Introduction

Chapter Four describes the results of the first cycle of the action research study and focuses on answering the first two of the research questions:

- How does a sample of isiXhosa speaking Grade 8 teachers teach elementary direct current electric circuit concepts to isiXhosa speaking learners? and
- Do learners and teachers have alternative conceptual models for concepts used in direct current electric circuits?

The research questions focus on two different groups of participants, namely the science teachers on the one hand and the learners of these science teachers on the other hand. The layout of the chapter followed this focus and the results of the data collection are presented by first reporting on the teaching practices of the teachers, followed by the conceptual models related to current in elementary DC electric circuits.

4.2 Results of the data collected from the teachers

Based on the thematic analysis and interpretation of the collected data, the following themes emerged from the data: PCK knowledge (which included the type of teaching strategy used), professional language, and level of subject content knowledge of the teachers. A discussion of the individual themes that emerged from the coded data of teacher problems is discussed in detail from section 4.2.1.

4.2.1 Theme One – PCK suitable for teaching simple circuits

As described in Chapter Two, PCK has various elements that each contributes to the successful teaching of a specific concept. The main theme PCK has been sub-categorised by addressing the use of analogies as a form of representation of the abstract concepts; the use of conceptual teaching strategies for active learning and its associated underpinning constructivist perspective on learning; and lastly the professional language associated with the teaching of science.

The first theme that emerged from the data collected in the first cycle of the research revealed a lack of knowledge about (and consequent usage of) analogies which can simplify the teaching of simple electricity concepts. Instead the teachers did not have a good understanding of the underlying constructivist learning theories prominent in science teaching; they used the textbook method or direct teaching predominantly in their teaching practice.

On a question by the researcher as to whether the qualified teacher makes use of any analogy when she teaches electricity concept, and if she does use analogies, to describe the analogy she used, the response was as follows:

> "***Yes, I do*** *[make use of analogies].* For example, *there is an* ***advertisement*** *about the danger of electricity and illegal connection of electricity then I tell-ahh-told them about that...mhm... advertisement because they love to watch TV."*

The unqualified teacher, on the other hand, admitted that she did not know about analogies, nor about constructivist teaching:

> "*I have never heard of this constructivist teaching method*."

The challenge faced by the teachers is their lack of knowledge about analogies as scientifically proven strategies that enhance understanding in science. There is conclusive literature that suggests that analogies have been used successfully as strategies that enhance understanding of complex concepts such as electricity in science education so that learners can be proficient in the reading, writing and understanding of science concepts (Asoko & de Boo, 2001; Chiu & Lin, 2005; Glynn, 2008). The teachers‟ lack of knowledge about analogies is quite alarming and exposes a deficiency in the teachers‟ PCK. It is also important to note criticism from various scholars levelled at the traditional method of teaching when teaching difficult concepts like electricity (Duschl, 2007; Schwartz et al., 2009).

When asked about the use of active learning principles during the teaching of a topic of such abstract nature as electricity, T1 was hesitant and evasive when responding to the question on how she used actual components of a simple electric circuit in her teaching, blaming the lack of a laboratory for her lack of using concrete examples of the components during her teaching.

T1: **"***Ahm … because we don"t have a laboratory in our schools, Ahm…instead of eh…because they know the wires, they know the bulbs and I use the symbols in the book so that they can know if I have used this particular symbol, that particular symbol means may be a battery, a wire, a switch.*"

T1 did not answer the question directly; instead a totally different direction is taken where the poor physical state of the school is addressed which I believe does not have direct bearing to the question asked.

Posner et al. (1982), believe that most research in science education focuses on the constructivist view of learning because learners use their existing knowledge to attribute meaning to new information. There is also consensus amongst scholars that the traditional textbook method encourages rote-learning while constructivist-informed teaching helps in building concept-formation by using models and analogies (Duschl, 2007; Glynn, 2008; Schwartz et al., 2009). The use of old-fashioned textbook methods in teaching difficult sections of science like simple circuits paints a daunting picture about the quality of the teachers" PCK, and in particular the use of teaching strategies that link abstract scientific knowledge with the familiar, home context.

Determining the type of teaching method used was not enough for my study as that information alone was not sufficient to address my research objectives. My other concern was to probe for reasons on why the textbook was used as the primary teaching strategy so that I could determine whether there were any gaps in the teachers" subject content knowledge and teaching strategies. While the objectives of the research questions require the identification of the type of teaching method used by the teachers, I believe that the reasons have a bearing on teaching and learning because the use of analogies as alternative teaching strategies will be shaped by the openness of the teachers to recognise flaws in their current teaching styles and be willing to change their usual teaching strategies.

The interviews revealed that the teachers use the textbook as the main source of subject content knowledge as T1 explained that:

> *"I use the symbols in the book so that they can know if I have used this particular symbol, that particular symbol means may be a battery, a wire, a switch."*

T2 was up-front and provided specific reasons on why she relied so heavily on the textbook as a teaching resource:

> *"… so I use the textbook and tell the kids that this symbol represents a cell, etc. This is what is needed in a test so I teach so that they can know the parts of a circuit diagram when they are asked in a test or exam."*

On the other hand, T2 explained that the textbook has examples and information which makes it an easy reference information tool. The textbook is used as a tool which ensures that specific subject content is passed from the teacher to the learners in a prescribed manner and in a certain time period so that curriculum objectives set by the department can be met.

While acknowledging that teachers‟ reliance on the textbook method is not a new phenomenon, as previous studies have shown, questions had to be raised about why it has been used so often (Hubisz, 2003; McCarthy, 2005). T2‟s verbatim extracts show that the textbook is used as a reference source for the learners about the meaning of the different symbols forming the different parts of a circuit diagram. The negative effect of this practice is that the over reliance on the textbook may lead to rote learning where learners do not get opportunities to understand concepts. T2 clarified that she only gives her learners information and exercises that are in the textbook because “*It‟s what is needed for them to pass in the test.”* A challenge may arise if this reliance on the textbook is left unchallenged and teachers continue to teach learners without providing the learners with meaningful opportunities to understand concepts (McCarthy, 2005).

Having realised that there was a gap in the knowledge about constructivism in both teachers, it became necessary to investigate which language was used by both teachers during instruction because constructivism considers greatly the role played by prior knowledge (which includes language) for understanding abstract concepts (Duschl et al., 2007; Lincoln & Guba, 1985; Schwartz et al., 2009). Taking into consideration Webb‟s (2010, p. 448) argument that ESL learners need to be assisted to “cross the borders between the informal language they speak at home” and the formal, academic language used in the science classroom, the role of language as an element of constructivism follows in the discussion. In view of the fact that both teachers and learners are ESL speakers, the use of familiar isiXhosa home language and ESL as language of instruction and learning has been examined in greater detail (see 4.2.2).

4.2.2 Theme Two - The professional language

Krashen (2003, cited in Bentley, 2004, p. 2) maintains that ESL learners acquire language through “comprehensible input” from the teacher during instruction.

Highlighting the critical role played by comprehensible input in content learning, Bentley (2004) argues that ESL learners will not learn if they do not understand the teacher‟s explanations. It is for that reason that the study delves in to find the distinct role played by language of instruction where English is the medium of instruction to ESL learners. Two sub-themes emerged under the main theme, namely code-switching for the purpose of teaching and learning and the loose use of isiXhosa by the teachers during their professional conversations.

Setati et al. (2002, p. 129), caution that mathematics and science educators are faced with the “double challenge of teaching their subject in English while learners were still learning this language”. Hence, educators try to resolve the dilemma arising by the lack of English communication ability with the learners by code-switching during the science lessons. Code-switching is the practice of teachers of using the learners‟ First or Home language in short phrases to elucidate abstract terms during an English medium instruction (Setati et al., 2002; Webb, 2010).

On a question by the researcher, both teachers revealed that they are using code switching because they believe learners do not understand if the lesson is presented mainly in English or to clarify certain difficult or confusing English concepts during the presentation of lessons in simple circuits.

T1: "*Mainly I am using English. But see[ing] that they don‟t understand, I go the mother tongue so that they will fully understand what I am talking about in this particular lesson."*

T2: "*I use English but the learners struggle with understanding so I use isiXhosa frequently to explain."*

On further probing both teachers revealed that the learners generally struggle with English. It was also established that the learners do not participate in classroom activities if the instructional language used by the teachers is predominantly English.

T2: "[*I*] *use isiXhosa mostly; but sometimes English. If I insist on English, most learners do not participate."*

Observing the teachers‟ reasons for code switching, teachers seem to have the perception that teaching abstract concepts such as those found in electricity in the mother tongue is more beneficial to their ESL learners than teaching these concepts in English. The teachers also stated they have reason to believe that presenting a subject as difficult as direct current electric circuits primarily in English to ESL learners may not yield meaningful learning. Hence, both teachers frequently switch from English to isiXhosa during their teaching to enhance the learners‟ understanding in the topic.

While the use of correct English as a language of communication and grammar usage did not form part of the objectives of the study, I could not neglect data captured in the interviews that indicates that both teachers were not fluent English speakers. Initially, extensive data analysis was based on T1‟s transcriptions because T2 refused to carry on with the audio-taped interviews. I analysed the frequent use of words like "*ahm*", "eh" and "*hamm*" as these words were surfacing frequently from almost every response given by T1. In isiXhosa, the quoted terms are generally known to signify hesitation and I believe that the use of these terms signify lack of confidence even in English. Although I did not take an actual numerical count of how many times isiXhosa words were used during the interviews, transcribed quotes support my judgement about the frequent use of isiXhosa:

T1: "*To give us more ways in which all those kids, all of them can understand even those who don‟t have the knowledge of what **i**-electricity is or what direct current is. Then, if we can get that somebody and give us (mhlawumbi) may be some lessons … "*

T2: "*I‟m helping the kids **qha** (only)…"*

4.2.3 Theme Three - Insufficient Subject Content Knowledge

Shulman (1986) emphasises the importance of educator subject matter knowledge by suggesting:

> *"The person who presumes to teach subject matter to children must demonstrate knowledge of that subject matter as a prerequisite to teaching"* (Shulman, 1986, p. 5).

The presence of alternative conceptions has to be identified in order to develop the teachers‟ pedagogical content knowledge (PCK), taking into consideration that subject matter knowledge and teaching strategies are important tools for a teacher as they form part of PCK. In order to determine the teachers‟ subject content knowledge (SCK) it was planned to administer the same diagnostic test that was developed for the learners and that focused on various current flow conceptual models to the teachers. Due to the refusal of both teachers to complete the diagnostic test used for the learners (as discussed in Chapter Three), field notes and responses during informal discussions were used to deduct the quality of the teachers‟ content knowledge (Duschl et al., 2007; Novak, 2010). Evidence of a lack of subject content knowledge has been gleaned from T2‟s assertion captured in this excerpt:

T2: "*They are not knowledgeable about it (topic in electricity) ok, so when they understand electricity it‟s also gonna be much more better. It‟s gonna be easy and better to also* ***save electricity*** *and understand the importance of* ***electricity*** *at the end of the day.*"

The teachers do not have a clear understanding of the development sequence of the concepts; but rather mention the more familiar safety aspects of electricity which are of a very public debate in South Africa at the moment. Similar to the familiar, intuitive conceptions of electricity that a learner is reported to bring to the classroom (Coll et al., 2010; Driver et al., 1994; Kibble, 2002), the unqualified teacher seems to bring her own familiar, intuitive conceptions to the classroom. The incorrect and vague use of abstract scientific concepts by the teachers indicates insufficient subject content knowledge for such an abstract section of the curriculum.

4.2.4 Discussion of the findings on the teacher problem identification phase of Cycle One

Evidence gathered from data analysis and data interpretation reveals three main findings pertaining to teacher problems identified during Cycle One, namely, the lack of knowledge about constructivist-informed methods like analogies and predominant use of textbook method, heavy use of isiXhosa in an English medium of instruction science class and insufficient subject content knowledge.

Previous studies by Duschl (2007) and Schwartz et al. (2009), have criticised and questioned the effectiveness of the traditional textbook method in teaching science, supported amongst others by McCarthy (2005) and Novak (2010). The findings of the study may raise a debate among the general public, teacher community and education department administrators on the quality of teaching and learning taking place in ESL schools, based firstly on the choice of the textbook as the sole traditional method of teaching by both teachers. Whilst not refuting the merits of the textbook; I believe that the most striking feature about both teachers in the study is their absolute reliance on the textbook as the sole teaching strategy without gaining or exploring knowledge of any other means of teaching a subject as abstract as simple circuits.

The success of analogies covers a long period in history and the consistent view is that analogies can promote concept understanding in teaching simple circuits (Hancock & Onsman, 2005). Data indicate that neither of the two teachers used analogies when teaching simple circuit concepts.

Probing further for a response on whether T1 knew and used specific analogies in her teaching or whether she could provide an example of an analogy that can be used in the teaching of simple electric circuits, even if she did not actually make use of the analogy in her teaching, T1 responded as follows:

T1: *"Yes, I do. For example, there is an advertisement about the danger of electricity and illegal connection of electricity then … I tell-aah-told them about that…hmh…advertisement because they love to watch TV."*

I gently probed T1 in the fear that she might start to feel uncomfortable and might withdraw from the study. The follow-up question asked her if she could provide any examples in textbooks of the use of analogies. T1 could not identify any examples and rather shifted the focus of the conversation away from analogies to a discussion around extra classes that are available for slower learners. It was clear that she did not want to further discuss the issue of analogies.

The second teacher"s response to the same probing question revealed a similar situation:

T2: *"I have not seen any teaching examples except the worked out calculations in the textbook. As I said before (in a weary voice), I"m not a trained science teacher so I don"t know any new or other strategies."*

T2 openly acknowledged that she had not seen examples of teaching methods in the textbook which may be used as analogies for teaching science. Also, T2 openly requested urgent help in order to help her cope with teaching simple circuits. Given that T2 lacks a science background; her caring attitude is shown by her zeal in helping learners to understand the subject better despite her handicap of being a substitute teacher without a science background:

T2: *"… I think it will be better if we could get some help, urgent help alright. I should get some help so that I can be able to actually bring that information to them so that they can have a better future."*

It is evident that both the teachers lack knowledge and understanding around the concept of analogies and the use thereof in the teaching of abstract concepts such as simple electrical circuits. However, both teachers expressed a need for assistance with the teaching of electrical concepts. Despite previous hindrances in data collection experienced in Cycle One, the urgency and willingness of both teachers to express the need for professional assistance with the teaching of electrical concepts led the study into the next phase.

It was consequently decided that an in service-training workshop (specifically for analogies as teaching strategies used in teaching simple circuits) should be developed as an answer to the teachers" call for assistance. It can be concluded that the teachers" lack of knowledge and consequently use of analogies to teach electrical concepts were some of the problems identified in the first cycle of the study.

Existing studies show that using the textbook primarily as a teaching method is not a unique feature of South African science educators (McCarthy, 2005; Hubisz, 2003). For example, United States English First language-speaking educators who took part in a study conducted by Peacock and Gates (2000) in McCarthy (2005) used the textbook as the main source of teaching. One of the similar views shared by USA educators in McCarthy (2005) was that the textbook was a valuable tool for preparation of lessons as it served as a foundation for new topics. Furthermore, McCarthy (2005) cites a study done by Elliot, Nagle and Woodward (1986) which found out that 90% of teaching time was spent on the textbook in primary science school classrooms. Lastly, Hubisz (2003) states that science textbooks are used primarily by science educators in the world as a guide on the content and skills set down in the curriculum.

The results of the study indicate that both educators use the learners" home language to a greater extent and this view is contrary to existing research explaining how learning occurs in urban schools (Setati et al., 2002). Educators in urban schools conduct science lessons in English, occasionally using the learners" main language to explain a few unclear concepts (Setati, 2002). Despite the teachers" noble views of using mother tongue to enhance understanding and class participation, I believe that the findings have adverse implications for education because questions may be raised firstly about the development of English language proficiency of the learners if the teachers are also found lacking in that aspect.

Earlier studies by Borges and Gilbert (1999) give a forewarning on the dangers of interchangeable language usage where teachers use every day mother tongue concepts as synonyms for scientific concepts, creating alternative conceptions in the process. For example, there are no known isiXhosa synonyms for science terms like electricity, power, current, energy, voltage and charge; hence isiXhosa speaking teachers and learners use the terms interchangeably. Secondly, the advantages of using isiXhosa largely in an English medium science lesson remain unanswered because assessment "question papers are in English" (Setati et al., 2002, p. 140).

I believe that a weakness in the medium of teaching raises a contentious issue concerning the role of the educator as an expert in the science classroom (Schneider & Plasman, 2011). As put by Govender (2012:15), I believe a "*sine qua non"* for effective teaching requires that teachers must communicate ideas explicitly; using language (in this instance English) and teaching strategies that help to elucidate the abstract concepts of a circuit diagram such as the difference between electric energy and electric current. How can an educator be able to bring about "student learning, student assessment" and implement teaching strategies efficiently if language development is poor (Duit, 2007, p. 8)?

The study established that educators lack sufficient training in Natural Sciences, analysed from the views of the substitute teacher and the spontaneous calls for assistance received from both educators. The findings of this study point to a situation where the educators‟ pedagogical content knowledge became questionable based on why the textbook was given preference by the teachers above all other proven methods. The results are supported by a study by Hubisz (2003) which disclosed that many USA middle schools science educators use mainly the textbook because they lack sufficient training in Physical Science. Insufficient training in Natural Sciences was characterised by the results of the present study which showed that educators lacked knowledge about analogies that can be used to teach simple circuits.

As the study was done at the beginning of 2010 when the curriculum was called the Revised National Curriculum Statement (2002), the teachers indicated that the Natural Sciences textbooks for Grades 8 and 9 did not have analogies as examples of teaching strategies that can simplify abstract concepts in simple circuits. In contrast with South African English ESL Natural Sciences textbooks, Frederiksen et al. (1999), raise a striking feature of textbooks written in English First language in Europe. Textbooks in English First language schools "typically rely on analogies" whereas South African textbooks are according to the teachers in this study, lacking analogous examples (Frederiksen et al., 1999, p. 810). Taking into consideration that both teachers rely on the textbook as a basic method of teaching, omission of analogies as examples could have deprived the teachers of an alternative teaching strategy that could have paved a way for better teaching of simple circuits.

I believe that that the lack of analogous teaching has an adverse impact on education as learners will learn science by rote learning where emphasis will be in substitution in formulae for getting correct answers and definitions of terminology. Hence, emphasis is put on quantitative problem-solving where learners are not shown how the abstract concepts are connected to the mathematical calculations of say, voltage (Frederiksen et al., 1999). Then, learners manipulate the left hand side of the equation without understanding the meaning, for instance, of calculating voltage in instances where there are two or more resistors with different resistances.

In agreement with Larkin and Chabay (1989) cited in Frederiksen et al. (1999), the study takes into account that:

> *But what do students learn in solving quantitative problems? Rather than considering what is happening within a circuit, students learn to use the circuit diagram and problem statement as cues to access formulas that they think fit the problem, to manipulate them algebraically to solve for the required result, and then to plug given quantities into the equations to calculate answer* (Frederiksen, 1999, p. 810).

In view of the knowledge gap in subject content knowledge and teaching strategies shown by the study findings, the educators‟ PCK needs to be developed so that the educators can transcend from novice status to subject expert level (Schneider & Plasman, 2011). The presence of alternative conceptions indicates that both educators are not confident about the subject content knowledge in the section dealing with simple circuits. There is consensus amongst researchers that alternative conceptions are difficult to change by ordinary traditional teaching; therefore a process of conceptual change is necessary to create opportunities of learning with understanding (Baser & Geban, 2007; Palmer, 2005). Hence, educators and learners as well have to be actively engaged in the construction and re-construction of knowledge by means of analogies which explain and predict scientific phenomena (Duschl et al., 2007; Heywood & Parker, 1997; Palmer, 2005).

According to Schneider and Plasman (2011), expert educators are characterised by increased knowledge and ability to adapt previously held incorrect ideas as new skills and knowledge is acquired. Therefore, the eagerness of the educators to seek assistance motivated me to develop a professional development workshop where PCK would be planned so that the educators could be expert educators in simple circuits.

4.3 Learner problem identification in Cycle One of the study

Kibble (2002) and Shipstone (1985) agree to the view that many learners give their own conceptual explanations when dealing with consumption of the electric current in a closed circuit. As discussed in Chapter Two of the study, the explanations given by the learners when dealing with consumption of the electric circuit are mostly intuitive and scientifically incorrect because of the influence of everyday language usage in the learners‟ environment (Coll et al., 2010; Driver et al., 1994). Hence, the study attempts firstly to examine whether learners have any alternative conceptions in simple circuits.

4.3.1 Type of source-consumer model identified in learners after pre-testing

Two main themes emerged from the pre-test diagnostic responses of the learners. The first theme addressed the presence of alternative conceptual models related to current in a simple electric circuit. The second theme was the level of reasoning and command of English as language of learning.

The first type of consumer model identified in the learners was the consumption model. The consumption model was analysed by looking at the learners‟ written diagnostic tasks by studying the drawings, focussing at the length of the lines at the point of entrance of the light bulb (A) and at the exit point (B) of the photo diagnostic item (see Annexure H).

Data analysis was based firstly on observations of events in a natural classroom setting where classroom observations were clearly written down in a field notebook without questioning the learners during the process. Thereafter, the learners‟ written work was checked for differences and similarities in the length and direction of the lines drawn (McNamara, 2009). Secondly, data analysis of open ended standardised interviews was done to establish the existence of alternative conceptions.

Finding out the presence and type of alternative conception currently held by the learners was pertinent to the study in order to allow the researcher to establish whether the use of analogies in the teaching of the electricity concepts resulted in any change in the learners‟ conceptual models held. The results analysed and discussed in this chapter were collected, based on the learners‟ responses to the second diagnostic test (see appendix E).

The study used literature reviewed in Chapter Two of the study to classify the conceptions held by the learners as belonging broadly to either the correct scientific model or the incorrect source consumer model (Çepni & Keleş, 2006; Shipstone, 1985). The source consumer model can again be subdivided into either a consumption model (using the size of the electric current as reference point) or the clashing currents model (using the direction of the current flow as reference point). Table 4.1 illustrates the indicators of the two alternative conceptual models, namely the consumption model and the clashing currents model that emerged during data analysis.

Table 4.1: The consumption and clashing currents model (adapted from Shipstone, 1985)

Consumption model	Clashing currents model
• straight line drawn before entering point A is longer than line exiting point at B • written learner explanation indicating that electric current is not equal at point A and B of the diagram or is bigger at A than at point B	• arrows of straight lines coming from both sides of the battery terminals and meeting at the light bulb • written learner explanation stating that the direction of the current is different at point A and B

Table 4.2 shows a summary of the results of the pre-test data collected from the participating learners revealing the type of source consumer model identified after performing the task, compared to the five learners who held the correct scientific conceptual model at the initial stage of the study. The majority of the learners (50 out

of 78) have the consumption model; whilst 23 out of 78 learners had the clashing model.

Table 4.2: Results of conceptions identified in Grade 8 ESL speakers' pre-testing, using photo diagnostic assessment item.

Type of Conceptual model	Number of respondents	Total number of respondents
1. Consumption model	50	78
2. Clashing model	23	78
3. Scientific model	05	78

In line with the qualitative nature of the study, learner engagement and interest in the pictorial diagnostic item provided another area of concern where the study probed for reasons why the learners were interested in answering the photo item rather than the circuit diagram consisting of symbols.

Learner Two (L2) gave a reason that "*lo mbane umnintsi kagesi xa efika*" (*the electricity [of the gas] is bigger when it enters*) to support why the electric current is thought to be bigger at point A than at point B. For example, the learner with the consumption model indicated that the current is "*no, is unequal*" but went on to conclude that the electric current flows in the "*same direction*".

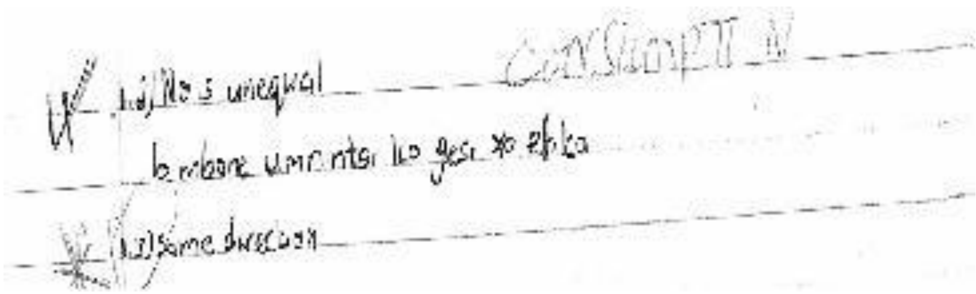

Figure 4.1: **Written explanation of a learner during pre-testing, showing consumption model**

The written statement from Learner One (L1) is a clear indication of the consumption model as the learner believes the electric current is different and the reason for that is "*its **used buy** there light bulb*". The correct statement should have read "*it‟s used* ***by*** *the light bulb*".

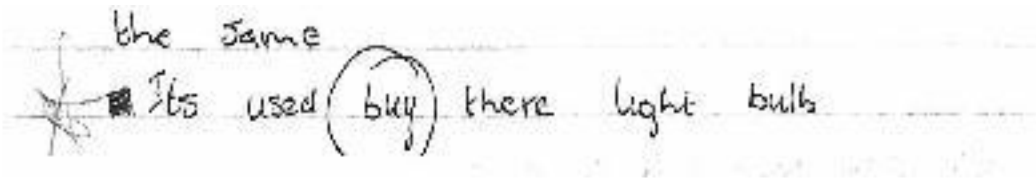

Figure 4.2: Written explanation of a learner holding the consumption model during pre-testing, illustrating a problem with the use of English

Learners share ideas and look for a solution to problems in the social world, including problems in the field of science, through language (Bentley et al, 2000; Driver & Erikson, 1983). It became evident that it is very difficult to understand what the learners are saying. The challenge posed by English is clear as can be seen from the use of the term "buy" instead of "by" in the written explanation as learners struggle to describe their thinking and understanding. It is also not just the incorrect spelling of words that is a cause for concern. The use of isiXhosa to explain thinking was illustrated in this answer:

Figure 4.3: Learner's written explanation showing consumption model, written primarily in isiXhosa

A person who does not speak isiXhosa would not comprehend what has been written by the learners and would fail the learners if it was a test that needed to be marked. There should be an in-depth investigation into the use of English in the classroom as the language of learning and teaching is English for these isiXhosa speaking learners (see learners‟ written responses).

A discussion of the findings of data analysis and interpretation in both the teacher and learner components of the study is presented in the next section.

4.3.2 Discussion of the findings on the learner problem identification phase of Cycle One

Findings of the study reveal that a majority of ESL learners hold the source-consumer model of electrical circuits, indicated by the presence of the consumption (50 out of 78 learners) and clashing currents (23 out of the 78 learners) alternative conception models. Only five learners out of 78, had the scientific model. The source-consumer model is indicative of the knowledge gap in the content under investigation (simple circuits). Also, teachers have alternative conceptions although theirs could not be classified under source-consumer model. In view of the knowledge gap in subject content knowledge and teaching strategies shown by the study findings, the educators‟ PCK needs to be developed so that the educators can transcend from novice status to subject expert level (Schneider & Plasman, 2011).

There is consensus amongst researchers that alternative conceptions are difficult to change by ordinary traditional teaching; therefore a process of conceptual change is necessary to create opportunities of learning with understanding (Baser & Geban, 2007; Palmer, 2005). Hence, educators and learners as well have to be actively engaged in the construction and re-construction of knowledge by means of analogies which explain and predict scientific phenomena (Duschl et al., 2007; Heywood & Parker, 1997; Palmer, 2005). According to Schneider and Plasman (2011), expert educators are characterised by increased knowledge and ability to adapt previously held incorrect ideas as new skills and knowledge is acquired.

The eagerness of the educators to seek assistance motivated me to develop a professional development workshop where PCK would be planned so that the educators can be expert educators in the topic dealing with simple circuits. Hence, Chapter Five presents the theoretical background behind professional development which deals with specific subject matter.

4.4 Chapter summary

Chapter Four has presented an analysis and interpretation of data; revealing a gap in the knowledge about the use of analogies to teaching electricity concepts, which is the main research question of the study. The initial intention of the study was to find out the type of analogy used by the teachers; however, data analysis revealed that the teachers do not know about any analogies that could be used to teach science. Therefore, Chapter Five presents an intervention strategy in the form of a professional development; requested by the teachers as a strategy to develop their subject content knowledge and topic specific content knowledge.

Chapter 5
Findings of Cycle Two
(Professional Development Intervention)

5.1 Introduction

Chapter Five is concerned with the outcomes of professional development and the use of a contextually appropriate analogy in teaching a lesson in simple circuits to ESL speaking learners. Data analysis of teachers‟ teaching strategies in Cycle One revealed a lack of and a need for knowledge about analogies in general, including analogies used in teaching direct current electric circuits in science. True to the nature of an action research design, the findings of the first cycle influenced the direction of the research. For that reason, an intervention strategy in the form of professional development was initiated to develop the teachers‟ subject content knowledge and teaching strategies.

Shulman (1987) in Depaepe et al. (2013), recognises the critical role played by the development of pedagogical content knowledge for teachers in training and also for those who are already in practice. Set against this background, a professional development was designed to offer teachers in service on-going educative support to cultivate their pedagogical content knowledge and develop their competence in the subject (Loughran, Berry & Mulhall, 2012; Novak, 2010; Summers et al., 1997). The culminated in the selection professional development of a contextually appropriate analogy that can be used in teaching simple circuits to ESL speaking learners.

This chapter will discuss the theoretical framework for the PDI, the structure of the PDI that culminated in the choosing of a contextually appropriate analogy for teaching simple electric circuit concepts and finally the reflections of the teachers on the professional development experience.

5.2 Professional learning community

The study takes the view that professional development does not solely rest on university courses, workshops, local and national conferences but accommodates the idea that "formal or informal learning communities among teachers can act as powerful mechanisms for teacher growth and development" (Desimone, 2009, p. 182). Teacher learning is viewed as a social activity. This view takes professional development beyond the traditional approach to a situative perspective Putnam and Borko, 2000). Brown, Collins and Duguid (1989, cited in Putnam and Borko, 2000) argue that knowledge is part of the context and culture of every activity that is performed by individuals. The situative perspective was extended to teacher learning, proposing three fundamental concepts namely: cognition is 1) situated in specific contexts; 2) social in nature; and 3) distributed across the individual, other persons, and tools.

Aligned with the situative perspective by Putnam and Borko (2000), scholars also have suggested various ways to engage in effective teacher learning opportunities of which professional learning communities are of importance to this study. A professional learning community (PLC) is "a group of people who take an active, reflective, collaborative, learning-oriented, and growth-promoting approach toward the mysteries, problems, and perplexities of teaching and learning" (Mitchell & Sackney, 2009, p. 30). The purpose of the professional learning community is to enhance the learning of the learners in the classrooms (Mitchell & Sackney, 2011). Such arrangements set up potential interaction and discourse which can be a powerful form of teacher learning (Desimone, 2009, p. 184). Mitchell and Sackney (2011) identify common characteristics for professional learning communities namely; a shared vision, collaborative work culture and willing reflective practice, engagement and experimentation.

5.2.1 Effective professional development

Desimone (2009) provided a theoretical framework of how professional development influences teachers, their instructional practice and the learning of their learners (see Figure 5.1).

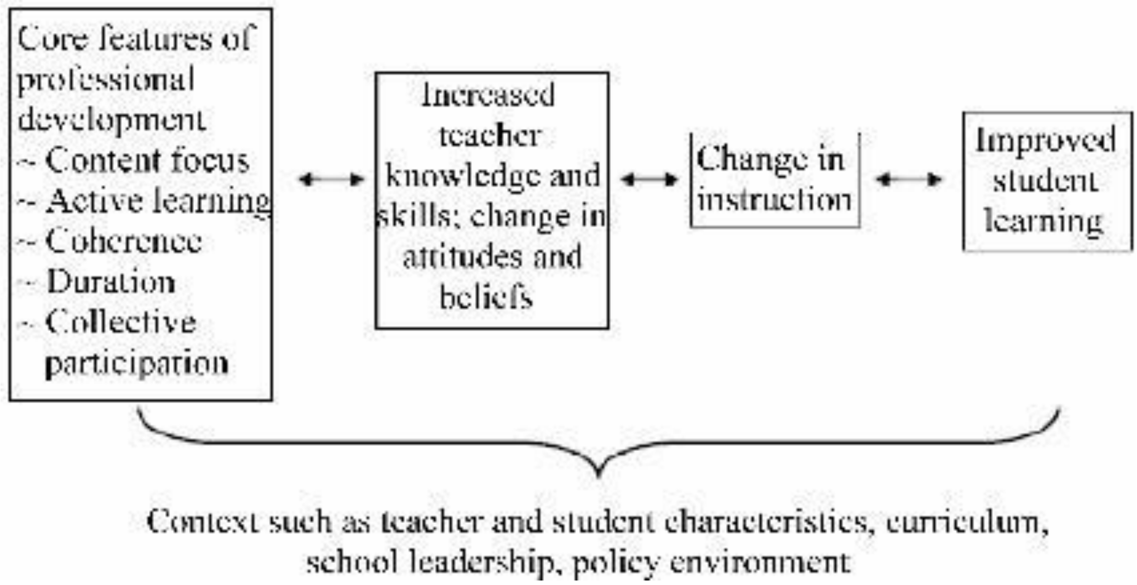

Figure 5.1 Desimone's (2009) conceptual framework for studying the effect of professional development on teachers and students.

The core theory of action proposed by Desimone (2209) includes four main steps. Firstly, teachers participate in effective professional development. Their participation in professional development, secondly, increases their knowledge and skills and/or changes their attitudes and beliefs. Given their new knowledge and skills (or attitudes and beliefs), teachers, thirdly, improve their instruction through changes in content, pedagogy, or both. Fourthly, the changes in their instructional practice promote increased student learning. In this model, context functions as a key mediating and moderating influence. Important contextual factors include, for example, student characteristics, teacher characteristics, curriculum, school leadership, policies at multiple levels, and classroom, school, and district environments.

Desimone (2009) identified core features of professional development activities as "those characteristics of an activity that make it effective for increasing teacher learning and changing practice and ultimately for improving student learning". These core features are: content focus, active learning, coherence, duration, and collective participation (Desimone, 2009). Content focus is regarded as may be the most influential feature of teacher learning. Research cited by Desimone provides evidence to a link between professional learning activities that focus on subject matter content and how students learn that content, and an increase in teachers‟ knowledge, skills and practice (Desimone, Garet, Birman, Porter, & Yoon, 2002; Smith, Desimone, Zeidner, Dunn, Bhatt, & Rumyantseva, 2007).

There is however a limited link between an increase in teacher knowledge growth and learner achievement, hence, the focus of the study will mostly be on the link between increased teachers‟ knowledge, teaching strategies and how the learners have understood the subject content after professional development. Specifically, she represents that: 1) core features of effective professional development are content focused, active learning, coherence, duration, and collective participation; 2) the way this effective professional development affect teachers‟ knowledge, their practice, and finally students‟ learning; and 3) contextual factors such as student characteristics, teacher characteristics (for example teachers‟ prior experience, content knowledge, beliefs and attitudes), and school characteristics are related to the effectiveness of professional development (Desimone, 2009).

The second critical feature of effective professional development is active learning. Active learning can take a number of forms, including observing expert teachers, followed by interactive feedback and discussion (Desimone, 2009, p. 184) or involving teachers in an activity that demands reflection on ideas formed and how they are using those ideas (Michael, 2006). Active learning makes it possible for teachers to establish the extent of their understanding in certain concepts of a particular subject (Anderson, 2002; Michael, 2006). As Loughran et al., (2012, p. 12) points out:

> *Many teachers come to find that their initial simplistic views of teaching are confronted when the intricacies of their work become clearer over time. Through this process, whereby a growing understanding of teaching begins to emerge largely as a result of learning through experience, a new appreciation of one‟s*

skills and abilities compels some to move beyond the simple delivery of information.

The third characteristic of effective professional development is coherence. Coherence is defined as the "extent to which the learning of the teachers is consistent with their knowledge and beliefs" (Desimone, 2009. p. 184). It is of utmost importance that professional development resonates with the knowledge and beliefs of the teachers at whom the professional development is aimed. It becomes imperative therefore that teaching strategies should form a link between the individual‟s social and cultural background (Coll et al., 2010; Snively & Corsiglia, 2000).

The duration of the professional development is the fourth feature which is linked to coherence in the study. Knowledge growth and change in practice needs time (Desimone, 2009). Therefore, any professional development should consider using materials familiar to the beliefs of the teachers (coherence) and ensure that the process covers a reasonable period of time (duration) in order to achieve understanding of concepts and skills in the particular subject content. Furthermore, it is important to get the teachers‟ collective participation in the professional development activities. Groups of teachers from the same grade, subject, or school should participate in professional development activities together to build an interactive learning community (Desimone, 2009). A detailed discussion on the structure of the PDI employed in this study is presented in section 5.3.

5.3 The structure of the professional development intervention for this study

The structure of the PDI was designed as a collaborative process involving the researcher, the two teachers and a university lecturer specialising in teaching electric concepts with analogies (the presenter of the workshop). These role-players constituted the professional learning community. The PDI almost took on the nature of mentoring with a one-on-one approach due to the fact that the first session was offered to each of the teachers individually (see Chapter Three).

In order to ensure that the various elements of effective professional development as identified by Desimone (2009) are incorporated in the PDI offered to the two teachers, the general structure of the PDI took the form of three structured topic-specific learning opportunities offered in the context of a professional learning community. The intervention strategy was designed to target the teachers‟ development in three sessions comprising:

- Session one where subject content knowledge development dealt with the consumption model of electric current in particular, and simple electric circuit concepts in general. This is in agreement with Depaepe et al. (2013), and colleagues‟ viewpoint that subject content knowledge must be dealt with before the pedagogical skills required to improve understanding of a topic is addressed.
- Session two focussed on the development of the Topic Specific Pedagogical Knowledge that can be used to teach simple circuits in a meaningful manner. The specific focus was on exposing the teachers to various analogies that are appropriate to simple electric circuits.
- Session three where the emphasis was on the collaborative development of a lesson plan and teaching of the lesson using the selected analogy after professional development.

5.3.1 Subject Content Knowledge development in Session One

Bearing in mind Shulman (1986, p. 5) who cautions that a person who presumes to teach subject matter to learners must show command of that particular subject matter as a prerequisite to teaching the subject. Ball et al. (2008), hold the view that teachers who do not know the subject knowledge well cannot be able to assist learners to learn the subject content. Therefore, the development of teachers' subject content knowledge was a priority in this study. The importance of teachers‟ conceptual knowledge in developing learners‟ understanding is confirmed by research in a South African context (e.g., Adler, Pournara, Taylor, Thorne, & Moletsane, 2009; Kriek & Grayson, 2009).

Session one consequently targeted the development and improvement of the teachers‟ own conceptual knowledge of simple electrical circuits. In the view of the dominant source-consumer conceptual model held by the participating learners (as identified in Chapter 4), the focus was particularly on the flow of electric current in a closed series connection to ensure that the teachers are able to effectively address this misconception held by the learners. The idea that the current is consumed in a circuit is referred to in this study as one of the elements of the source-consumer model (Shipstone, 1985).

The facilitator used a practical hands-on approach where the teachers were actively engaged in their own learning of simple circuit concepts. During the presentation, key points on simple circuit content dealing with the importance for a complete electric circuit pathway were clarified. Specifically, the focus was on the components of an electric circuit (cells, bulbs, switch, ammeter and voltmeter); the size and direction of the electric current in a series circuit; measurement of electric current with an ammeter and the source-consumer model as an alternative conception.

The facilitator employed Kolb‟s experiential learning principles (Kolb, 1984) by introducing the first session by linking the participant teachers‟ experience of teaching simple electric circuit concepts to the experience of their science teacher colleagues internationally by stating that:

> *"Teaching electricity is not an easy [activity]. It is very difficult because electricity is a kind of concept which is … a mental construct. We can‟t see electricity, we can‟t feel electricity."*

The act of establishing a connection between the teachers‟ own experience and teachers in other parts of the world provided a vehicle for the active engagement of the teachers in the professional learning community, providing them with the safe space where they can confidently engage in the learning experience offered to them (Kolb, 2004). As the activity proceeded the teachers were more willing to expose their vulnerability around the teaching of simple circuit concepts.

5.3.2 Reflections on the first contact session of the professional development initiative

Based on observations made by the researcher during the PDI, the difference in behaviour between the two participants was evident. The qualified science teacher (T1) eagerly participated in the activities. T1 responded freely and correctly to the questions posed by the facilitator and also displayed more confidence and precision in the execution of the practical assembling of electric circuits and was able to use newly acquired information in different circumstances (Mitchell & Sackney, 2009; Moon, 2006). Observing T1‟s actions and non-verbal behaviour (quick action and smile), I could detect that she was excited as she actively engaged with the lesson. She behaved like a learner who understood the topic for the first time. T1‟s active learning and fearless engagement in the activities display Mitchell & Sackney‟s (2009) view that:

> *"It is exactly this kind of excitement that is the test of true learning. If classrooms and lessons do not bring forth similar energy and excitement, then learning is probably not happening"* (Mitchell & Sackney, 2009, p. 22).

Teacher two on the other hand did not actively participate in the activities. Mindful of the fact that she was an unqualified science teacher she was more engaged in note-taking. She was also more tentative in her responses to questions.

5.3.3 Topic Specific Pedagogical Content Knowledge in Session Two

Having established in Cycle One that the teachers showed a lack of understanding in the meaning of the term „analogy‟ and the use of analogies as teaching strategies, it became essential that action needed to be taken where the teachers could be given assistance in knowledge and skill acquisition. Also, research literature in Chapter Two of the study highlighted the importance of the pedagogical content knowledge of the teacher as a key factor which plays a role in boosting teacher confidence and improving learning experiences of the learners (Appleton, 2003; Summers et al., 1997). As discussed in chapter two, topic specific pedagogical content knowledge

(TSPCK) entails the following components: learners‟ prior knowledge, curricular saliency, what makes a topic easy or difficult to understand, representations (including analogies) and conceptual teaching strategies (Mavhunga & Rollnick, 2013). The focus of this phase of the study was on the development of the teachers‟ use of representations (an analogy in particular) to teach the flow of electric current in a simple DC circuit.

During the planning of the second session of the PDI, the prerequisites necessary for the development of PCK as set out by Loughran et al. (2012), were taken into consideration. The teachers should experience concrete examples of the analogies and how to implement them in a classroom. These concrete experiences act as a way of scaffolding fundamental knowledge that is hidden in the content and that has to be understood by the learners. The ideal is to get teachers to use scientifically accepted analogies that fit the context of the learner and that form part of the learners‟ culture.

The lesson included examples of analogies such as the bicycle chain analogy, string analogy, Charlie Coulomb‟s analogy, Uncle Volty‟s service station, creatures‟ analogy, little men, filling station and the water flow analogy (Asoko, 2002; Glynn, 2008). See Chapter Two for a more detailed discussion for most of these analogies. The choice of an appropriate analogy should be based on its efficiency in supporting the learners to understand basic knowledge embedded in the content. Therefore, the choice of a relevant contextually appropriate analogy was based on its ability to map the familiar base concept of the analogy with the new, target concept. The process is referred to as concept mapping by Glynn (2008). In the topic under study, the analogy must for example map the parts of the simple circuits such as the cells, the conducting wire, the movement of electrons, the size of the electric current and the influence of the light bulb as a resistor.

As the facilitator explained children‟s intuitive ideas, an illustration on Asoko and de Boo (2001) on Figure 5.2 shows how the string analogy addresses for example; the myth that most students have that the cell produces electrons. The rope forming the string analogy is marked with inked dots which represent electron charges and this is my complete circuit.

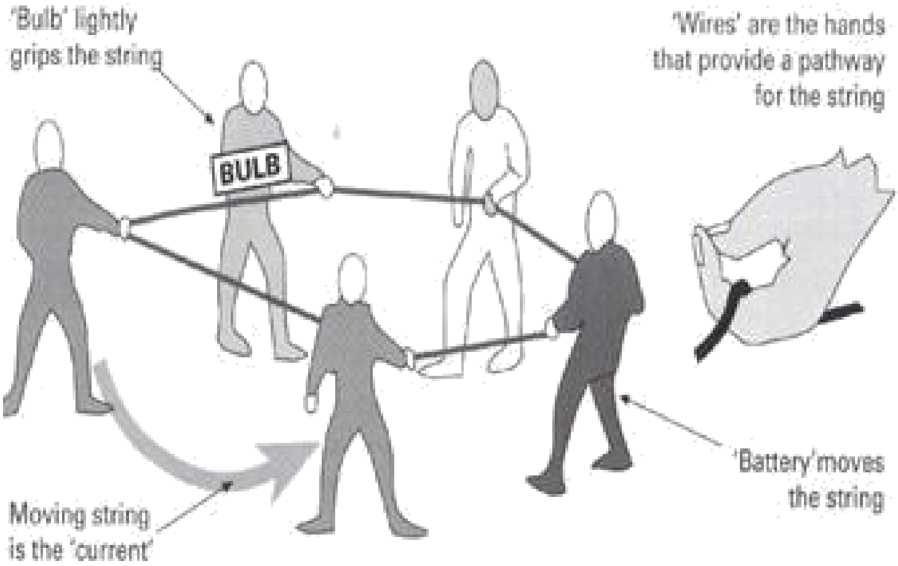

Figure 5.2: **An illustration of string analogy** (adapted from Asoko & de Boo, 2001, p. 53)

The different positions played by the people holding the rope play a critical role in mapping out target and base concepts of analogy (Figure 5.2). For example, the moving string which represents the electric current. The teacher who is holding the string tighter represents the resistor which is in this case, a light bulb. The hands, through which the string glides, represent the conducting wires in the circuit. Counting the number of dots passing through represents the ammeter as shown by the illustration of the string analogy in Figure 5.2. In other words, the alternative conception that the battery produces electrons can be changed by using the string analogy.

It was critical at this stage to link the parts of the string analogy with the specific parts of the simple circuit so that the teachers and their learners should not be left with an impression that they were merely playing a game (Guerra-Ramos, 2011). The teachers were asked to map the common features of the string analogy against the target concepts of the simple electric circuit (see Figure 5.3).

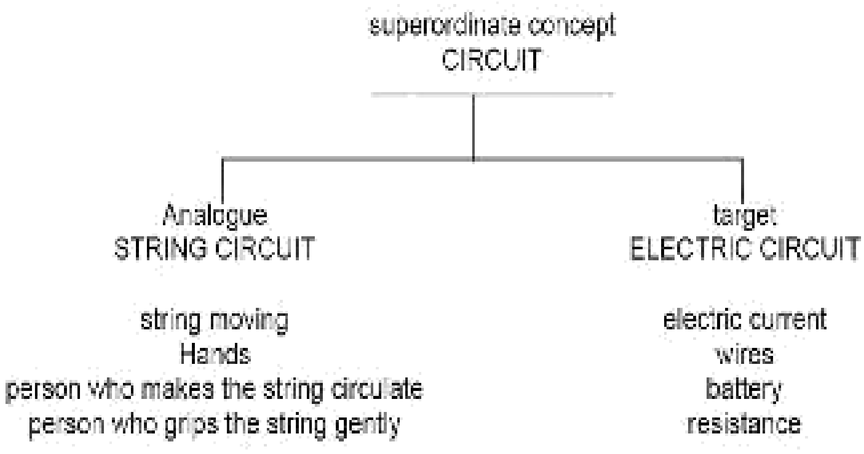

Figure 5.3: Representation of the 'string circuit' analogy (Guerra-Ramos, 2011, p. 33)

At the end of the demonstration of the various analogies available for use in teaching simple circuits, the string analogy was chosen as the most contextually appropriate analogy by both teachers. The teachers identified the following criteria as important in their decision:

- the string analogy"s concept mapping ability based on the simplicity in linking the base concepts to target concepts for ESL speakers;
- familiarity of the string analogy with their learners" environment;
- easy availability of the resources needed for the string analogy. All the material of the string analogy is known and easily available in the learners" world, and as such the analogy easily formed a bridge between the learners" known and unknown worlds.

5.3.4 Reflections on the second contact session of the professional development initiative

As reflective practice is one of the important elements of the learning strategy as it indicates professional growth, school development and on-going advancement, the facilitator created ample space for the teachers to freely share their views and teaching practices (Mitchell & Sackney, 2009). During the whole presentation, the teachers spontaneously shared their views verbally and non-verbally as they reflected on their past experience and their instructional practice in electricity. As the teachers reflected on their learning, they described how the facilitator presented the lesson on the types of alternative conceptions and shared their views about the challenges facing ESL learners due to language limitations and familiar incorrect analogies from their environment. I noted the sharing of ideas between the qualified science teacher (T1) and the unqualified science teacher (T2). Both were on equal ground with regard to the instructional use of analogies because both teachers were learning about analogies for the first time.

The main difference between the teachers was the subject content knowledge of simple circuits, of which T1 had an upper hand. It became apparent that T2 was gaining confidence and believing in herself more during the analogy session by contributing to the lesson more than during the first session on subject content knowledge. As the presentation progressed and the facilitator left clues like unfinished sentences for the teachers to answer, T2 got involved and answered the question without being asked to:

F: "*Going back to the string analogy, counting moving dots is the…".*
T2: "*Ammeter"".*

T2 seemed to have understood the session on the use of analogies well and could actively link the components of the analogue with target concepts of DC electric circuits. As the presentation was coming to an end, T1 whispered to T2 that she was hearing for the first time that there are children‟s stories that could be used to teach simple circuits so easily.

What transpired during the period of reflection was the extent to which the teachers have managed to confront their own intuitive ideas and how exposure to knowledge about analogies has helped them to reconstruct their own alternative conceptions (Mitchell & Sackney, 2009). For example, they found out that they shared the misconception that flex wire used for bedside lamps (seemingly being only one wire between the plug and the lamp) is actually two wires inside a plastic coating.

T2 made a remark during the demonstration about how:

> "… *easy it is to understand what is happening in a circuit diagram, when a teacher has apparatus"*.

The question of the availability of resources raises the issue of poorly resourced township schools.

5.3.5 Session three – Practical application of knowledge into instructional design

The purpose of the third session in the PDI was to apply the pedagogical knowledge about analogies gained in the second session in the context of planning a lesson in which the best suited analogy for the context of the teachers are used. The Teaching – With – Analogies (TWA) (Glynn, 2007; 2008) strategy discussed in Chapter Two was used to plan the lesson on. Immediately after session two of the PDI, we had an hour session where we agreed on a date for lesson presentation, consolidated critical areas of the string analogy and agreed that the lesson plan should be in the form of a simple lesson scheme (see appendix F).

After the teachers made the choice of the string analogy as the contextually most appropriate analogy for their learners, it was agreed upon to collaboratively plan a lesson using the selected analogy to teach the components of a simple DC series circuit, as well as the current flow in such a circuit. The teachers agreed to teach the lesson individually in their own schools using the collaborative designed lesson.

The six steps of the Teaching– With – Analogies (TWA) strategy for the successful implementation of an analogy (Glynn, 2007; 2008) discussed in Chapter Two was used to plan the abridged lesson scheme.

Table 5.1: The link between the string analogy and simple circuit concepts

Link between the string analogy and content on current electricity	1. **Loop of the string** which goes around and back to the teacher = a **closed circuit** in which the same amount of electric current leaves the battery and goes back to the battery so that the current does not get used up. 2. **Teacher who controls** the movement of the string = **battery**. The string is available in the whole circuit all the time, however; movement will only be initiated when the battery person makes the string to move). Hence, the battery gives the „push‟. 3. **Moving dots** = **flow of charges** (current) which is moving in a closed circuit. This means that all parts of the string are moving at the same rate just like the electric current which is the same everywhere in the series circuit. 4. Holding the **string** firmly = **Bulb** (resistor). 5. **Two people** holding string firmly = resistors **in series.** 6. **Counting** moving dots = **ammeter.**

Firstly, the target concept of the lesson (the movement of electrons in a closed series circuit) will be introduced. Thereafter, learners will be reminded about similar situations where an analogous relationship can be made between the various parts of the string analogy and the components of a closed circuit. Thirdly, similar features of the analogy and the new concept will be identified. Next, a connection has to be made between the base target and the target concept based on similar attributes between the two concepts (see table 5.1). Weaknesses of the analogy have to be identified to avoid creating alternative conceptions and finally, a conclusion will be made between the functions of the analogue concept and the target concept.

5.3.6 Reflections on the third contact session of the professional development initiative

It was very important that an analogy be selected that fits in the context of the learners in order for it to make the topic more understandable. For example, using analogies that do not link with the learners‟ familiar daily life environment may confuse learners further as one of the teachers commented:

> *"You can‟t use the ski analogy in the Eastern Cape as the students are not familiar with skis."*

I asked the teachers why they selected the string analogy while there were other analogies presented. T2 responded looked at T1 and said: *„let me answer this one‟* and she explained:

> "T*he string game is made of easy material as the kids normally play skipping games."*

I probed further, wanting to know if they understood the mapping base concepts (game parts) to the target concepts (the DC electric circuit concepts). Even at this stage, T2 voluntarily answered and indicated that:

> "*I followed the game and the points which were explained by [the facilitator] in the string compared to the bicycle parts example.*"

From the teachers‟ responses, a theme emerged that the string analogy was chosen because it fitted the context of the learners because it was made of material of a skipping rope which was readily available in the homes of the learners.

T1 joined in the conversation and suggested that:

> *"It may be because we practically played the string game instead of thinking about the parts of a bicycle or water going down a hill*. *The string game takes away the stress of thinking about the big-science terms."*

She went further and added that:

> *"The lesson on current flow boosted my understanding and has made it easy to teach with this game."*

T1 added that the string analogy

> "… *is easy to understand because the parts of circuit like the moving electrons, can be seen in the string because they are marked…The kids would like and understand the game and nothing needs to be bought to do-no expense to our poor schools."*

T1‟s explanation indicated that active interaction by means of a practical demonstration simplified understanding of simple circuit concepts. A picture emerged where the simplicity of the string analogy compared, for example, to the parts of a bicycle, justified the selection of the string analogy.

Another feature that emerged from T1‟s explanation was that the string analogy fitted the context of the learners because no expense would be incurred by buying instructional material, given that both schools are situated in a low-income area.

T1: *"Problem with a bicycle; somebody must have a bicycle to know these parts - but a rope and koki [pen] are known by most people.*"

T2: *"Problem with bicycle is we understand it but how will we get it in class to explain the parts to the kids?"*

Towards the end of the planning session the confidence of T2 (the unqualified science teacher) started to dwindle. Despite having gone to such lengths to familiarise both teachers to the content, T2 refused to present the lesson, mentioning fears about her lack of sufficient subject content knowledge in simple circuits as her reason for withdrawal from teaching. Her fear of presenting the lesson was clearly evident in her remark:

> *„‟I know that the dots on the string represent electrons, but what if I‟m asked something else by these kids?"*

I was anxious at this stage of the study as I felt that my study was in danger due to the possible withdrawal of the unqualified teacher. To my relief, T1 willingly offered to present the lesson using the chosen string analogy to the learners in both schools, allowing the study to continue as planned. T2 also agreed to continue to be part of the lesson by observing the lesson presented by T1 in order to gain the benefit from seeing the teaching strategy in action and sharing her reflections on what happened. This was an important step in the study because T2‟s reflections about the use of the selected analogy and its use in science teaching were valuable in building the credibility of the study (ensuring that the views of both teachers were acknowledged).

In trying to get the exact reasons for the withdrawal of T2 from teaching the lesson after engaging positively during the presentation by the university facilitator, T2 stated that she refused because she was unable to map the correct science terminology to the various parts of the analogy. Mindful of Argyris and Schön (1978) in Mitchell and Sackens (2009:25); I tried to understand T2‟s refusal based on the "espoused theory" and "theory in use" which states that there is a big difference between what individuals want to do („espoused theory‟) and what we really do („theory in use‟) (p. 25). Therefore, I am compelled to explain T2‟s reluctance to teach the lesson due to T2 sensing that T1 was fast and confident in giving the correct answers whereas she was still struggling. In other words, there was still a gap between what T2 wants to teach the learners (espoused theory) and what she can really teach the learners (theory in use).

In this instance, in response to one of the questions from the facilitator during session two, the facilitator was pleased by T1‟s correct answer (judged from facilitator‟s pitched voice) after T1 had given a correct response and the facilitator said:

> *"You‟re quite right, you‟re correct! So, let me draw it on the chalkboard. On the ammeter, the reading was 0?"*

Hence, T2 may have thought that her slow progress in understanding the topic may elicit a negative response from the facilitator and colleagues as well. T2 may also have thought that her slow understanding and slow engagement with the lesson may give undesirable results - in this case, bad results, when teaching the learners. Hence, the collaborative abridged lesson scheme was taught by T1 only out of the two teachers partaking in the study.

5.4 Reflections on about professional development as a whole

Collaboration is an important feature of a professional learning community because teachers are able to come together and "discuss issues, sort out challenges, plan new learning opportunities and discuss new curriculum ideas" (Mitchell & Sackens, 2009, p. 26). The professional learning community consisted of the researcher, the two participant teachers, a lecturer from the university and another teacher who joined the workshops. In order for learning communities to function effectively, the learning in the professional community should involve "working together towards a common understanding of concepts and practices" (Stoll & Seashore Louis, 2007, p. 3). The teachers commented on the inclusive nature of the presentation. They experienced an increased sense of security to engage in a lesson presented by an expert without fear of criticism.

The PDI was developed based on the teachers expressing the need for assistance from the professional learning group members. They displayed vulnerability when they acknowledged their lack of knowledge and consequent need for support. As T1 commented:

> *"I think it will be better if we could get some help, urgent help, alright!"*

Vulnerability in professional learning communities can be defined as "the exposure of the self in the presence of others" (Pignatelli, 2011, p. 221). When one makes the active choice to make oneself vulnerable by requesting help with any aspect of teaching, there is a greater opportunity of reframing knowledge, moving „in the midst of uncertainty‟ and seeking strength from others (Latta & Buck, 2007, p. 194).

Considering that both teachers attended the professional development showing lack of sufficient subject content knowledge and topic specific knowledge in analogies used in teaching simple circuits, teacher reflections discussed in Chapter Five showed that teachers have improved their SCK and TPCK after the workshop. What transpired from teacher reflections about the value of the professional development was illuminated in the following:

- Exposure to analogies as new teaching strategies that simplify abstract concepts in science;
- Increased interest in analogies indicated by search for books with more examples of analogies;
- Content focus development by means of a practical demonstration of how the electric current flows in an electric circuit;
- Increased confidence shown by the ability to select an analogy considered appropriate to the learners and teach the lesson using the selected analogy;
- Effect of the duration of the professional development on understanding specific topic knowledge and new strategies;
- Sharing of knowledge in a professional learning community such as universities as a way of gaining more knowledge and confidence in teaching the subject;
- Importance of a safe environment created by a teaching sequence which encourages free participation.

Results on the PDI give an overall positive picture where both teachers have benefited from the intervention in terms of an improvement in terms of their understanding about analogies and selected electricity concepts. Evidence of the experienced teacher‟s understanding is her analysis of an analogy she found in the new Natural Sciences textbook; comparing an analogy found in the new curriculum Natural Sciences books in terms of its effective base and target mapping. After evaluating the newly found textbook analogy, the teacher still preferred the string analogy as an appropriate analogy for the learners residing in this area and she felt she had "*gained sufficient confidence to present lessons in simple circuits."*

5.5 Chapter summary

In conclusion, professional development can be used effectively as a strategy targeting the improvement of Topic Specific Content Knowledge of science teachers. Specifically, an understanding of how analogies are used and the selection of a contextually appropriate analogy is an indication of increased knowledge on how to use constructivist strategies in teaching simple circuits. However, the duration of the

PDI must be longer to focus more on content so that the teachers can teach simple circuit concepts confidently with sufficient subject matter knowledge.

The next chapter will focus on the implementation of the chosen string analogy by the teachers, followed by an evaluation of the effect it had on the learners" conceptual understanding of the flow of current in a simple DC circuit.

Chapter 6

Findings of Cycle Three
(Implementation of analogy)

6.1 Introduction

In Chapter Five, a professional development on various analogies used to teach direct current electric circuits internationally was presented. Findings of the professional development were presented revealing a particular type of analogy preferred by the teachers and learners as being the most suitable to teach and learn about the flow of electric current in a closed series circuit connection. Results of learner post-testing after lesson implementation using the selected analogy were provided. The findings of both teacher and learner participants were provided in the narrative form, supported by verbatim quotations from transcribed interviews and field notes.

In this chapter, findings regarding the perceived increased knowledge in constructivist strategies such as analogies after attending professional development will be presented, supported by the teachers‟ reflections. The results of the learner post-test will be contrasted with the pre-test to support the general idea that emerged from data indicating that the learners‟ understanding improved after exposure to a lesson using a contextually appropriate analogy. The findings will be substantiated by relevant literature and transcribed interviews. The chapter will conclude by discussing the educational implications of the findings, future direction of the study and steps taken to ensure trustworthiness and maintain the ethics of the study,

6.2 Teaching of the lesson in simple circuits using chosen analogy in Cycle Two

The following themes emerged from the data: the use of professional language and the effective implementation of the string analogy.

6.2.1 Professional language

Analysing the professional language used in the classes during the teaching, the following three sub-themes emerged: the loose and confusing language use to express concepts of a simple DC electric circuit; the incorrect language usage and an over-use of isiXhosa as language of teaching. A sample of statements is given to illustrate or highlight the problems. Brief comments are also given, in parentheses, when appropriate.

T1 repeatedly referred to the concept *atoms* in her explanation instead of the concept *electrons*:

> *"Because this current is equal in your circuit, and the dots in the string analogy, represent the* ***atoms*** *are moving [be]cause immediately they stop (pulling of the string) it stops. I-****atoms*** *(the atoms) are not moving, then immediately they start pulling again; the* ***atoms*** *will start moving again."*

It is evident that more in-depth concept development still needs to happen in order to get the teacher‟s content knowledge to a sufficiently sophisticated level to eliminate such examples of incorrect use of subject terminology. As a researcher, I could not disturb the lesson and make the correction without offending the teacher and breaking the trust relationship between us. After class, we discussed the lesson with the teachers and I carefully highlighted the error, of which she acknowledged the interchangeable use of atoms instead of electrons and promised to correct the mistake.

Examples of the loose and confusing use of language to explain the electricity concepts are intertwined with examples of the over-use of isiXhosa in the explanations, as can be seen in the following extracts from the lesson.

> *"It‟s very important to know ukuba ngaba (that) when you want your electricity to…to..work; there must be no gaps in between so that your electrons can move fluently around kungekho nto izakuyiphazamisa (without anything disturbing the flow of electrons)."*

"*Pull…they have a chemical energy from the battery. This chemical energy is being transferred to being a light energy and heat energy, and when they are cooling…kuzakubakho ubushushu aphe zandleni zakho…" "(there is going to be something warm in your hands) so it‟s transferred into light energy and heat energy."*

The concept of a closed circuit was explained as follows:

"*Ukuba ngaba inokuqhawuka le ntambo (if this string can break), uyakufumanisa ukuba ngaba uzakuyitsala lo (if the other one pulls the string), iphelela kuye, xa eyitsala lo, (the string is left with this one)."*

6.2.2 Effective implementation of the analogy

The lesson planned for the implementation of the analogy was underpinned by the principles underpinning the TWA model in order to ensure the meaningful learning of simple circuit concepts (Glynn, 2008). The TWA model was therefore used as an analytical frame for the instructional implementation of the string analogy by T1.

Based on the lesson scheme planned in Cycle Two of the research, the teacher was expected to follow the agreed upon example of the lesson guide using the TWA model and to teach the lesson as presented in Table 6.1 where all the visible, macroscopic features of the string analogy were used to illustrate the invisible, microscopic features of the electric current. Moreover, the teacher was also expected to explain where the analogy breaks down; in other words; which areas of the electric current cannot be portrayed by the analogy (Glynn, 2007; 2008).

The abridged lesson was not successfully implemented as discussed collaboratively by us during the planning stage (including me as the researcher and the unqualified teacher). During the presentation of the lesson, the teacher failed to make "a systematic comparison, verbally or visually, between the features of the analogue and target" (Glynn, 2008, p. 114). The teacher was effectively unable to map the features of the base or analog concept and the target concept in her teaching sequence.

Table 6.1: A conceptual representation of an analogy with its parts reflecting the string-electric circuit analogy (adapted from Glynn, 2008, p. 114)

	String Analogy **Base Concept**	**Electric Circuit Target** **Concept**
Feature 1	Loop of the string	Closed circuit
Feature 2	Moving dots	Flow of charges
Feature 3	Hold string firmly	Resistor (bulb)
Feature 4	Two people holding string firmly	Resistors in series
Feature 5	Counting moving dots	Ammeter
Feature 6	Teacher who controls movement of string	Battery giving the push

The use of the string analogy did manage to engage some of the learners in the learning activities. Academic engagement was identified as one of the problematic areas in the first cycle of the study. The familiarity of the materials used to teach with the string analogy created a friendly and relaxed atmosphere as illustrated by the teacher‟s comment when she entered the classroom with the skipping rope:

> *"I heard you when I was coming in. [You think] that you gonna play umshinxi.."(isiXhosa name of a skipping rope game).*

When the same learners were invited to come forward and participate in the demonstration, they were eager. Unfortunately, this level of engagement only extended to the group of learners who participated in the demonstration of the string analogy. The level of classroom engagement for the rest of the learners was quite disappointing. When the teacher asked questions to the class, the non-participating learners did not participate and left the answering to the learners who formed part of the string-analogy. The learners, who volunteered to play the various parts of the string, were more actively engaged by providing verbal answers to questions asked by the teacher as compared to the learners who were watching the demonstration.

Most questions were met with complete silence as the teacher tried to verify whether they followed the lesson. The learners‟ non-participation may perhaps be due to the use of English where they may have felt threatened as they had to answer in English, whereas the lesson presentation was mostly in isiXhosa.

What clearly emerged from the analogy demonstration was that the learners were struggling a lot with expressing themselves in English because those who managed to answer did so in the vernacular. It was evident then that English as language of learning and teaching was a big problem. The non-responsiveness of the learners may have been one of the reasons why the teacher reverted to a direct teaching strategy by telling the learners about the analogy in isiXhosa, but in the process failed to connect the elements of the string analogy to the target concepts of electricity.

Another perturbing question remains; did the learners (who were seated) see the relevance of the analogy to learning or did they view it as a game? As highlighted earlier in Chapter Two; teachers should guard against being carried away with the narrative (in the analogy) rather than anchoring conceptual structures and scientific reasoning (Glynn, 2008; Palmer, 2005). In this instance the learners may have focussed too much on the game instead of the link between the analogy and the abstract concepts they are targeting since the teacher talked a lot and explained more about the game rather than the connection between the analogy base concepts and the targeted, abstract concepts. Perhaps learners were still struggling to articulate their thoughts since they were still trying to comprehend the relationship between the analogy and the actual concepts of the DC electric circuit since the teacher did not manage fully to link the concepts.

6.3 Learners

The second version of the pre-test (appendix E) was administered as a post-test to the learners with the aim of determining any change in their conceptual understanding due to the use of the string analogy in the classroom. I conducted individual semi-structured interviews with six learners after they had completed the post-test to assess whether their ideas had changed after the implementation of the selected analogy. Also, I wanted to find out if the selected analogy was viewed as familiar and made conceptual understanding in simple DC electric circuits easier to understand.

6.3.1 The results of the Post-Test

The learners‟ drawings and written responses to the questions on the post-test was analysed using the same thematic analysis technique and coding strategy as was used and described in Chapter Three (see section 3.4.1). The isiXhosa answers were transcribed into English before any analysis and interpretation could be done.

Table 6.2: Description of learner conceptions on simple circuit concepts after the use of a contextually appropriate analogy

Type of Conceptual model	Number of respondents in Pre-Test	Number of respondents in Post-test	Total number of respondents
1. Consumption model	50	18	78
2. Clashing model	23	6	78
3. Scientific model	5	54	78

Table 6.2 presents a summary showing that the use of the contextually appropriate string analogy yielded positive results because more learners (54 out of 78) had developed the scientific model in the post test compared to 5 of the 78 participating learners, in the pre-test. Seemingly, the learners had changed their initial source-consumer models and gradually built a theoretical framework of knowledge where they could link their previously acquired knowledge to new concepts. In a way, the learners seem to have engaged in superordinate learning as the abstract pieces of knowledge seem to have been related to the known, prior knowledge of mathematics in this instance (Novak, 2010).

During the informal interviews, I asked the teachers if they had told their learners to write numerical values denote equal lines. Their response was „no‟. Both teachers indicated that they were surprised by the level of reasoning that had developed over this period as initially (in pre-test) the learners‟ written work was incomprehensible, mostly in isiXhosa and very few learners attempted to respond in writing. The learners seemed to be functioning on a higher level of reasoning as their explanations were more descriptive, showing that they had managed to make a connection between new and prior knowledge (Posner et al., 1982; Schwartz et al., 2009). For example, during the pre-test, their drawings had no units of measurements to indicate „equal length‟ but now, they were putting in units and mathematical signs like equal (=) (see Figure 6.1).

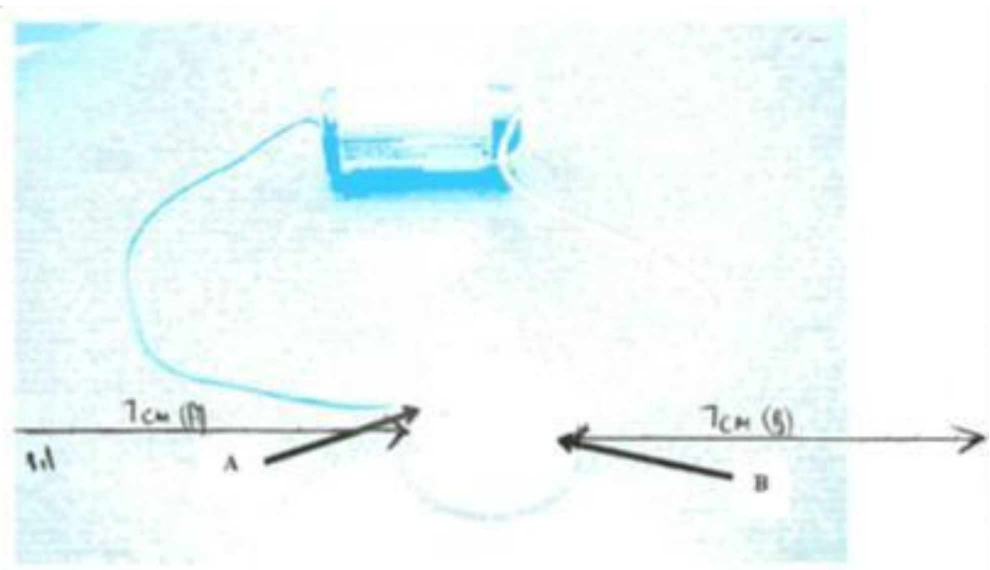

Figure 6.1: A learner's response in the post-test, with scientific model

6.3.2 Results of the learner interviews

After the teaching of the lesson using the chosen analogy, six learners were interviewed to gain their reflections on the diagnostic item used for the post-test, as well as the effectiveness of the string analogy for understanding electricity concepts. The learners were asked to compare the first and the second versions of the diagnostic tests and to provide reasons for their choice. Some of the responses given were as follows:

L2: *"It‟s easy to understand because everything is* ***physical.*** *You can* ***see*** *it and you can t****ouch*** *it, you* ***know (batteries and bulbs****) from my house."*

L3: *"There are pictures here which show the* ***actual thing****, the apparatus used on the particular diagram. That‟s why I‟ve chosen this one: I* ***know the pictures****. In your* ***daily lives*** *we use batteries and light bulbs and wires. It‟s more like a* ***vision, you can see it****."*

L6*: "It‟s because Miss, it (colourful picture) gives a* ***clear[er] understanding*** *than the symbols because* ***symbols are difficult*** *to understand and this one (pointing to colourful picture) is easier."*

A common theme emerged, showing that the photo circuit diagram was selected on the basis of being easy to understand as it consists of actual, physical, visual and tangible components that are familiar with the learners‟ environment. The symbol circuit diagram is regarded as difficult because it consists of symbols. The learner observations are critical to constructivism as recognition should be given to learners‟ prior knowledge (Palmer, 2005).

When learners were asked to give their views about the analogy used, they revealed that the string analogy was appropriate because it was „*easy to understand*‟, „*physical*‟, and „gave *a vision*‟ and developed an understanding that „*the current flows with the same speed and same energy right through the circuit*‟. The learners explained the suitability of the analogy due to the following reasons:

L2: "I understood that the current flows with the same speed and same energy right through to the bulb and from the bulb to the battery. It‟s like a circle."

L6: "The energy it uses to flow (in connecting wires) is the same as the energy which it uses to enter the light bulb."

L5: *"It‟s the same because the bulbs don‟t use the whole energy of the battery."*

Moreover, the learners seemed to have gained more confidence after the analogy use because the learners, who volunteered during the post-test period for the interview, seemed more competent in terms of language and reasoning than those who came during the pre-test. For example, the learners‟ post-test responses were in grammatically correct English with correct scientific reasoning as shown by this example:

L4: "*I understood that the electrical current stays the same and moves in one direction from the battery to the light bulb and then from the light bulb back to the battery but in a one-direction. I think so that the electric current is the same in series no matter what."*

6.4 Reflections of teachers on teaching the analogy

The teachers were in a better position than I as they knew the academic capabilities of their learners. Both teachers confirmed by suggesting that the learners who came for the post-test interview were more intelligent and language proficient than the previous group we had in the pre-test. However, the teachers shared that after the pre-test; learners had a discussion about the photo circuit diagram where they talked about how the question on the electric current should have been approached. Perhaps, all the learners (regardless of academic performance) developed a good understanding of what was required of the question and managed after the use of the analogy, to link prior knowledge with the new knowledge.

Given that information, I enquired if the use of the same diagnostic test item had not put the learners in a favourable position; however, both teachers stated that the learners generally perform poorly even when given test memoranda as a form of test preparation. In their usual class assessments, only the good learners take time to prepare adequately by using the memo. Therefore, the success of the post-test, viewed from the increased understanding of the scientific model, should be taken as a proper reflection of the positive aspect of the analogy used. Furthermore, the qualified teacher suggested that perhaps the analogy may have reminded the learners about mathematical conceptions and they have linked that information and applied it to answer the question.

6.5 Discussion of findings

The following developments were noticeable and emerged from data analysis: 1) many learners were writing their responses in English; 2) more learners had the scientific model; 3) correct, scientific reasons were given for the size and direction of electric current in a series connection; 4) string analogy is a contextually appropriate analogy which simplifies abstract concepts of DC.

Results on the PDI give an overall positive picture where teachers had benefited from the intervention by summarising the views about the critical features of the professional development. The study can claim success on the improvement in terms of analogy understanding as both teachers indicated that they have gained new knowledge which they can they apply in their classes after the professional development initiative. The success of the professional development is evident in the case of the experienced teacher who initially had no knowledge of analogies but ventured further to analyse other analogies presented in new books.

The success or failure of the professional development has been viewed against the critical features proposed by Desimone (2009), discussed in Chapter Five of the study. One of the critical factors of professional development which have emerged from the study is the important role played by the development of the content focus. The study has shown that although the unqualified teacher understood the analogy and actively participated during the presentation, she was not confident to teach the lesson. The important role of subject content knowledge should not be underplayed as shown by the unqualified teacher‟s post-test views that *„I felt I did not have enough knowledge as I was not a science teacher‟.*

The ability to understand how to use analogies is shown by the experienced teacher who made a comparison in terms of concept mapping; comparing an analogy found in the new curriculum Natural Sciences books in terms of its effective base and target mapping. After evaluating the newly found textbook analogy, the teacher still preferred the string analogy as an appropriate analogy for the learners residing in this area and she felt she had "*gained sufficient confidence to present lessons in simple circuits".*

What can also be gleaned from the results is that although professional development seems to be ideal for developing teachers‟ skills, the duration of such professional development plays a critical role in preparing the teachers sufficiently for effective teaching. As far as the PDI on subject content knowledge is concerned; both teachers were still lacking in using correct simple circuit terminology in their teaching. For example, the qualified teacher was still using incorrect terms like "atoms" instead of "electrons" while teaching the lesson after the professional development. Equally so, the unqualified teacher felt insecure and did not attempt to teach the lesson after the PDI as she declared that she lacked sufficient content knowledge in simple circuits. Overall, a short period has a negative impact because it cannot provide sufficient PCK to teachers who lack basic subject content knowledge in the subject; like the unqualified science teacher.

Another important aspect is the duration of the professional development where a shorter period is not regarded as sufficient by the teachers to adequately prepare them for effective teaching using analogies. Basic to teacher development is the need to first develop the subject matter adequately before developing the PCK. With regard to the experienced teacher, the time span of the PDI also presented some challenges pertaining to correct scientific terminology. In analogies, the qualified teacher progressed effortlessly as she could understand how the analogy works. However, the teacher could not adequately link subject content with the analogue concepts. In other words, the teacher was unable to link the base concept to the target concept although she had sufficient subject content knowledge as an experienced science teacher.

What can be gathered from the study is that there was an improvement after the professional development initiative as teachers initially did not know analogies but after PDI; they knew them and the qualified teacher ventured further to analyse other analogies presented in new books. However, the short period of the professional development did not cover sufficiently all the aspects of TSPCK required by the teachers; proof that the duration is one of the core features of professional development. Findings of the study also reveal that initially both teachers were not confident about teaching simple circuits and requested help but now the experienced teacher was confident about teaching the lesson and selecting an appropriate analogy for the learners. The confidence of the qualified teacher indicated that she has developed a higher level of self-efficacy compared to that of the unqualified teacher as she persisted in to perform the task that was agreed upon, that is; teach the learners with the chosen appropriate analogy (Chularat & DeBacker, 2004; Zimmerman et al., 1992). As an indication of the success of the PDI, at the end of PDI the experienced science teacher came out confident enough to teach the lesson even in the school of the unqualified teacher.

I believe that the enthusiasm shown by the qualified teacher by comparing analogies in new textbooks indicated increased knowledge and growing confidence in her topic specific pedagogical content knowledge (TSPCK). As highlighted in Chapter Four of the study, I believe that a weakness in the medium of teaching (English in this instance) raises a contentious issue concerning the role of the educator as an expert in the science classroom (Schneider & Plasman, 2011). However, the qualified teacher seems to have reasonably become more sophisticated in her thinking over the period she was involved in the professional development, including the time she collaborated with her peers in the planning of the abridged lesson guide (Schneider & Plasman, 2011). In essence, the qualified teacher was progressing incrementally from novice to expert performance as her teaching skills (in terms of analogy knowledge) were becoming more sophisticated.

Finally, the transformation from theory to practice or from espoused PCK to enacted PCK does not proceed automatically. There are many factors that may influence this developmental trajectory (Heritage, 2008), such as time, the teacher‟s initial content knowledge and the teacher‟s self-efficacy. Although some improvement was detected in the enacted PCK of the qualified teacher (T1), the improvement was short-lived. During the first instructional implementation of the TWA strategy after undergoing the professional development she reverted to her familiar teaching style of informing or telling the learners about the analogy instead of implementing the learner-centred teaching strategy required, making the analogy effective in assisting the learners to learn the abstract concepts.

The analogy cannot be successful if it is not linked to a teaching strategy that focuses on conceptual understanding (Mavhunga & Rollnick, 2013). The short-lived nature of the improvement may be a consequence of many issues. For example, research incorporated in Desimone‟s framework shows that teachers‟ personal characteristics such as their prior (subject) knowledge influence their individual learning pathway. This was clearly evident in the learning pathways of both the participating teachers.

The unqualified teacher‟s (T2) lack of content knowledge prevented her from even attempting teaching the electricity concepts, while the qualified teacher on the surface seemed to have developed enacted PCK, which in the end broke down when she reverted to the direct teaching strategy and the use of incorrect terminology.

6.6 Chapter summary

The chapter presented the implementation of the professional development. What has emerged from the professional development is, more emphasis should be on content focus as a strategy that can develop teacher confidence and self-efficacy. On the learner component, teachers should use contextually appropriate analogies critically to ensure that learners achieve the desired results and adhere to the mapping criteria to ensure that learners understand what has been presented. The next chapter presents recommendations and implications of the study in future.

Chapter 7
Conclusions and Recommendations

7.1 Introduction

This study set out to determine the use of analogies in the teaching of simple electric circuits for ESL learners from a township school. The purpose of this chapter is to unify and synthesise the findings in an effort to answer the research questions. A conclusion will be presented, projecting a picture of the current state of Natural Sciences teaching and learning in ESL township schools and henceforth; raising implications of the findings, particularly to the education department, and making recommendations for future practice.

7.2 A broad summary of the research

The initial aim of the study was to investigate the type of analogies used by the two science teachers when teaching simple electric circuit concepts topics in simple electric circuits. Based on the original idea, the following research question was formulated:

> *To what extent does the use of a contextually appropriate analogy contribute to the development of elementary direct current electric circuit concepts in isiXhosa speaking Senior Phase learners and learners?*

However, data analysis revealed that the teachers lack any knowledge of analogies that could be used to teach Natural Sciences. In view of the problem that surfaced, the study had to be adapted to address the teachers" lack of knowledge about analogies. Fortunately, my choice of education action research methodology accommodated a redesign of the plan by fitting in cycles that could address the changing circumstances. Therefore, a research design with three cycles emerged from the identification of teacher problems in the study.

The following research sub-questions were formulated:

- How does a sample of isiXhosa speaking Grade 8 teachers teach elementary direct current electric circuit concepts to isiXhosa speaking learners?
- What are the current conceptual models related to elementary direct current electric circuit of a group of Grade 8 learners and their teachers?
- Which existing analogy is considered as appropriate to the social background of the learners by isiXhosa speaking teachers?
- What are the perceptions of the teachers and the learners regarding the usefulness of the selected analogy for their understanding of the identified concepts?

A brief overview of the main focal points of each chapter is presented in this section.

Chapter One presents analogies as constructivist informed teaching strategies that have been used historically to simplify abstract science concepts including simple circuits. The influence of English as the LOLT to ESL learners is discussed in relation to studies recognising language as part of culture. Topic Specific Pedagogic Content Knowledge (TSPCK) is identified as an area of concern due to realising that teachers do not know analogies, lack confidence and subject content knowledge.

Chapter Two introduces literature to reveal persistent challenges that impede the correct conceptual understanding of simple circuit concepts in learners. In this study, the challenges have been classified under the term, „alternative conceptions‟.

Different analogies that have been used to modify learners‟ alternative conceptions are presented.

Chapter Three gives details about the cyclical process in which the qualitative action research was followed. A background is given to the design of the three cycles undertaken in the study, including the participants, data collection tools, data analysis, data interpretation and ethical considerations of the study.

Chapter Four details how Cycle One was implemented amongst the teacher and learner component of the study. A discussion is given on the merits of professional development as a strategy that can be employed to resolve the identified problems on the teachers‟ PCK.

Chapter Five presents a discussion of literature supporting professional development, specifically the development of SCK and TSPCK. Detail is given about teacher participation in the professional development and how a contextually appropriate analogy was selected by the teachers.

Chapter Six discusses the implementation of the chosen analogy to the learners. Detail is also given about the findings, showing the results of learner post-testing after being taught with analogy. A discussion is given about teacher and learner reflections about the usefulness of the analogy, seen against the background of available learner post-test results.

7.3 Assessing the quality of the research

As a teacher who studied my own colleagues and learners, it is important to understand that a major goal of action research is to promote change that supports student learning and success. To attain this goal we need to be able to trust the results of our work and be confident our conclusions are accurate. Various techniques were used during the process of conducting the research, as well as in producing the product of the research (this research report).

The classification of Anderson and Herr (1999) was used to establish the validity of the research findings – outcome validity, democratic validity and catalytic validity. Process validity ensured that the actual action research conducted shared the epistemological and ontological features of action research and whether the research process used in the study addressed the research questions. It is evident from the structure of the research report that the research questions formed a central focus of the research process and that the process was that of illuminating the multiple realities by interpreting the subjective perceptions of individuals during the construction and reconstruction of these multiple realities (as described in sections 3.2.2 and 3.2.3).

Staying true to the epistemological features of action research as described above, also ensured that the democratic validity of the study featured increasingly throughout the research as there was collaboration between the two teachers and the researcher, for example; during the planning and design of an abridged lesson guide with selected analogy. Catalytic validity was established in the transforming of the participants and the deepening of their understanding of the complexity around the teaching of simple electric concepts.

Another way to ensure validity is to constantly be looking for other explanations or anything that might disprove our findings. This is a difficult thing to do since we are often vested in our theories about what is taking place. But asking "what else could explain what I am seeing?" can help us avoid any blind spots we may have and strengthen our research. Approaching classroom action research as a cycle allowed me to refine and strengthen my findings. Each time I moved through the cycle, there were new opportunities to question, observe, and reflect. In this sense, my research builds upon itself to enhance my understanding of teaching and student learning.

This is in line with Cho and Trent‟s (2006) view of validity as a process moving away from an application of „the right criteria at the right time‟ to a process of „thinking out loud‟ about researcher concerns, safeguards, and contradictions continually.

Trustworthiness has been established through the use of data triangulation, member checking to establish credibility in the findings and by providing an audit trail of the various decisions (Denzin & Lincoln, 2005; Pine, 2009). The study has striven for triangulation by including various sources of data tailored for the specific questions to be addressed in each of the different cycles of the study. For example, in Cycle One, learner problem identification saw a three-fold design of the pre-test diagnostic item consisting of circuit diagrams in symbols; a simple black and white sketch and a colourful, photo diagram. In addition, standard open-ended learner interviews were audio-recorded and transcribed as evidence of the true collection and reflection of learner data. Referential adequacy has been maintained in the study as all data collected and analysed has been kept and isiXhosa to English translations have been done by a Head of Department of isiXhosa.

7.4 Limitations of the research

The study was small scale research with a small sample. However, the nature of qualitative research allowed for the emergence of thick descriptions of the individual. Moreover, the study does not infer any generalizations based on the findings.

If I can be given another opportunity to redo the study, I would increase the number of teachers and learners participating in the study in order to afford more teachers the opportunity of accessing new knowledge that would assist in developing their teaching skills.

7.5 Conclusions and implications of the study

The results of qualitative data analysis had the following themes on the teacher component of the study: lack of knowledge about the term „analogy‟ and use of analogies as teaching strategies, use of code switching and insufficient subject content knowledge. A conclusion derived from the data is based on the themes that emerged from the study. A two-fold exposition of the conclusion is drawn from the data and presented, targeting the themes that developed from the teacher and learner participants in an effort to answer the research questions.

Having established in Cycle One that the teachers showed a lack of understanding of the meaning of the term „analogy‟ and the use of analogies as teaching strategies and subject content knowledge, it became essential that action needed be taken where teachers could be given assistance in knowledge and skill acquisition. Data analysis also showed that both teachers rely heavily on the textbook to teach simple circuits. Professional development of teachers is regarded as "a critical factor in the improvement of education" (Lombard, 2007, p. 18). Also, research literature in Chapter Four of the study highlights the importance of topic pedagogical content knowledge as a key factor in boosting teacher confidence and improving learning experiences of the learners (Appleton, 2003; Summers et al., 1997). Hence, a suggestion from the teachers and a request gathered from data collected in the interviews conducted in Cycle One necessitated a workshop on the use of analogies in science for the two participating teachers.

An intervention strategy was planned to develop the teachers‟ PCK, thereby continuing with the cyclical nature of educational action research (Summers et al., 1997; Lichtman, 2013). The professional development was planned so as to allow the sharing of ideas by all stakeholders including the teachers because this was a co-generative study which required the input of experienced and knowledgeable university researchers and teachers as well. The express intention of the professional development was to select an analogy which was useful to teachers as a teaching strategy to improve learner concept understanding in simple circuits. The professional development was successful because it was planned to focus firstly on content as one of the critical factors (Depaepe et al., 2013). As a result, the development of SCK was done during Session One of the professional development.

Mindful of the fact one of the teachers was an unqualified science teacher who was a substitute for the school‟s science teacher who was on long leave; it was not surprising to find that there were different development trajectories between the two teachers. The qualified science teacher showed signs of increased knowledge in SCK and TSPCK, evident from her increased meaningful participation during the professional development. The teacher‟s active engagement with the subject content development section of PD was evidence of increased self-awareness of doing the right thing. In other words, the PD refreshed the teacher‟s SCK and raised her self-efficacy on science teaching (Bandura. 2006). As discussed in the PD section in Chapter Four of the study, the teacher performed calculations correctly and finished up sentences during the presentation such that the facilitator was surprised and excited by that experience. Although the teacher still had oversights in professional language as in the use of the terms „atoms‟ instead of „electrons‟; on the overall; the teacher understood the critical concepts in simple circuits during session one of the PD.

The qualified teacher showed distinct signs of transformation where she changed the usual textbook method to the constructivist method. What is evident from the teacher;

is that the capability to use more learning strategies (contextually appropriate analogy in this case) enabled her to persist with the given task as compared to the unqualified teacher (Zimmerman et al, 1992). The unqualified teacher participated actively during the Second Session where analogies were introduced to the teachers. However, the unqualified teacher refused to teach the lesson after attending the PD and getting involved in the collaborative plan of the cyclelesson. The teacher‟s refusal to teach the lesson as in „I am not a science teacher, so I don‟t have enough knowledge‟ indicates low self-efficacy. The development trajectories between the two teachers put them on two extremes. On one extreme, the unqualified teacher lacked SCK and had low self-efficacy, evident in her refusal to teach the agreed upon lesson. At the end, the qualified teacher gained sufficient SCK and self-efficacy such that she continues to teach the lesson as agreed upon. Moreover, the qualified teacher goes beyond teaching her own class; she became confident to teach the class of the unqualified teacher. Implications then are teachers need professional development to radically build their SCK and self-efficacy. In the provision of the PD, schools should refrain from using unqualified teachers as that action is counterproductive to learning and teaching.

The findings of the study indicated a differentiated developmental trajectory (Heritage, 2008) for the two participating teachers (admitting that they represent the two extremes of science teacher profiles in SA), although they received the same PDI. The transformation from theory to practice does not proceed automatically. The importance of practice when it comes to the effective implementation of newly acquired knowledge such as TSPCK and its associated teaching strategies cannot be over emphasised. The teachers should also not just be made aware of various ways of representing abstract concepts to learners; they should be afforded the opportunities to practice these representations and its associated teaching strategies to build their confidence in their own ability (teacher self-efficacy). The development of the associated professional language also needs time.

Research Question Two: What are the conceptual models related to current flow in simple direct current electric circuits held by a group of Grade 8 learners and their teachers?

Data analysis and interpretation of learner diagnostic pre-tests, revealed that learners have the source-consumer model. The prevalent type of source-consumer model was the consumption model, evident in the total of 50 learners out of 78 who believed in that alternative model whilst few learners (5 out of 78) had the correct scientific model. Literature review and clarification of terms have explained the various types of source-consumer model exhibited by the learners. What was also observed in the study was the learners‟ poor use of English; clearly seen from the use of incorrect, illegible and incomprehensible written data in English. The data had to be translated from isiXhosa to English; in some instances; even the isiXhosa words which have been written down didn‟t make sense. Therefore, the professional development was set out to equip teachers with the knowledge of how researched analogies that can be used as strategies designed to improve learner understanding.

During Session Three of the study, a post-test diagnostic learner test revealed an improved picture of learner understanding in the concepts of simple circuits. The improvement was substantial as more learners developed the correct scientific model while the number of learners with consumption and clashing currents model dwindled rapidly after being taught with the selected analogy. Reasons given by the learners at the post test interviews showed that the use of the analogy improved their understanding. The identification of alternative conceptions in teachers could not be done since they did not participate in the diagnostic testing. However, thematic data analysis showed that the teachers use scientific terminology incorrectly, hence the development of the theme indicating insufficient SCK.

Research Question Three: Which existing analogy is considered as appropriate to the social background of the learners by isiXhosa speaking teachers?

The string analogy was chosen by both teachers and learners as well, as an appropriate analogy. Reasons given by the learners included the following; ability of the analogy to simplify the parts of the circuit due to being „physical‟ „visual‟ „can be touched‟ „familiar and known‟ „easy to understand‟. The teachers also revealed that, given the fact that their schools are poorly resourced the string is made out of cheap and available material. Therefore, the string analogy can be used effortlessly in their underprivileged schools. While generating knowledge in the study; outcome validity investigated how far the outcomes of the research met the intended purposes. For instance, the learner post-test results were judged from data analysis of the semi-structured interviews to confirm that the outcomes (improved learner understanding) have been influenced by the use of the contextually appropriate analogy. The learner interviews were triangulated with the analysis of their written responses and teachers‟ reflections after the professional development.

Research Question Four: What are the perceptions of the teachers and the learners regarding the usefulness of the selected analogy for their understanding of the identified concepts?

The second session of professional development saw the teacher use new strategies that could work as models of abstract phenomena, which brought a shift from the traditional way of textbook method. A scientific model is an "abstract, simplified, representation of a system of phenomena" where key features are used to make explanations and predictions (Schwartz et al., 2009, p. 633). The teacher engaged the learners by modelling the learning process using the string analogy as a model, indicating that her knowledge was not static (Anderson, 2002). The teacher also used easily available material like the string, instead of the textbook (Anderson, 2002). As the teacher interacted with the class, there were interactive discussions between the learners involved in the demonstration and the teacher, although class participation was not at a maximum due to seated classmates‟ minimum participation during the interaction; the teacher had to check for understanding, use of analogies, meaningful teacher-learner interactions and assessments as opposed to mere note-taking (Brown & Brown, 2010). Further, teachers who create possibilities for interactive discussions also create opportunities amongst the learners for conceptual change where learners change their initial, incorrect views after sharing their views with other learners.

In Chapter Two, section 2.2.2 of this study, Lee (2005) argues the lack of English proficiency in ESL learners may cause learning barriers due to learners‟ inability to link the familiar knowledge from their culture with school science content. There was a marked improvement in the number of learners who responded in writing (post-test) compared to the pre-test. The increase may be due to increased learner confidence and improved simple circuit concept understanding after analogy implementation. The implications in connection with language are: the Department of Education should consider including African Languages as a medium of instruction and learning, in circumstances where learners are not English First Language speakers. Learning barriers may be due to current education policy context which emphasises the development of English as a language without giving attention to the development of the learners‟ first language. Therefore, the use of English Language is a communication tool which is used during a discussion to make known one‟s point of understanding, views and problems (Edmonds, 2002). It becomes imperative then that teachers have to ascertain whether learners are interacting with each other in class. That would create opportunities for the isiXhosa speaking learners to learn and be examined in their own language, but learn English as a language as is the case with the nations.

7.6 Recommendations

The first recommendation addresses the importance of teachers‟ subject or content knowledge to teach the mostly abstract concepts found in the Physical Science component of the Natural Sciences offered in Grades 8 and 9 in the South African schooling system. It would be interesting to determine whether the practice of requiring unqualified teachers to teach the Physical Science sections in the senior phase syllabus contributes to the poor performance of the learners in Physical Science in Grade 12.

The second recommendation is to take a more focused look at the professional development of science teachers. The crucial value of teachers‟ experience and knowledge with regard to student learning is increasingly being acknowledged (Mundry, 2005:9) in the context of professional development. Professional development therefore requires an inductive, problem-centred approach (Spector, 1993, cited in Steyn, 2008) that relates to teachers‟ context. Context in this sense includes a teacher‟s “awakening awareness of one‟s inability … to perform according to one‟s own expectations” (Steyn, 2008, p. 17), as was the case with the unqualified teacher during the third implementation cycle of the study. At the end, she became aware of her inability to perform according to expectations and as such declined the opportunity to teach the lesson to the class (see section 5.3.6).

The third recommendation is for further research to be done on the concept of TSPCK required by teachers for the various diverse contexts found in the South African school system and the associated learning progressions of science teachers. Lee (2005) argues that learning progressions are the successively more sophisticated ways of thinking about ideas that follow one another over a broad span of time. Based on data analysis of the teacher component of the study, it has become apparent that Natural Sciences teachers may generally lack knowledge about the use of analogies as strategies that can be used in teaching Natural Sciences.

Furthermore, teachers should examine the research on science teachers‟ pedagogical content knowledge (PCK) in order to refine ideas about science teacher learning progressions and how to support them.

The fourth recommendation focuses on the use of Desimone‟s framework for professional development. As Lee (2005) argues, the lack of command of the English language will create learning barriers which may impede development of ESL learners in Natural Sciences. Therefore, it would be interesting to determine whether Desimone‟s framework can be used to stipulate further direction of initiatives for science teachers‟ professional development by developing programmes which focus on content knowledge and topic specific content knowledge so that ESL learners can benefit from new teaching strategies.

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Appendix A: Permission to collect data from Eastern Cape DoE

MAR.10.2011 12:07 041 4034420 DEPT EDUCATION PE #2741 P.001 /001

Province of the
EASTERN CAPE
EDUCATION

Port Elizabeth District
Ethel Valentine Building • 5 Sutton Road • Sidwell • Port Elizabeth • Eastern Cape
Private Bag X3931 • North End • PORT ELIZABETH • 6056 • REPUBLIC OF SOUTH FRICA
Tel: +27 (0)41 4034400 • Fax: +27 (0)41 4510193 • Website: www.ecdoe.gov.za

Enquiries: Dr Nyathi Ntsiko E-mail: nyathi.ntsiko@edu.ecprov.gov.za

Ms A. Simayi
Researcher
Nelson Mandela Metropolitan University
c/o Head of Programme for Masters Studies in Education
Fax: 0415049695

Dear Ms Simayi

REQUEST FOR PERMISSION TO CONDUCT RESEARCH IN DEPARTMENTAL SCHOOLS: GQEBERA SECONDARY SCHOOL AND TYHILULWAZI SECONDARY SCHOOL: PORT ELIZABETH

I refer to your letter dated 09 March 2011.

Permission is hereby granted for you to conduct your research on the following conditions:

1. Your research must be conducted on a voluntary basis.
2. All ethical issues relating to research must be honoured.
3. Your research is subject to the internal rules of the school, including its curricular programme and its code of conduct and must not interfere in the day-to-day routine of the school.

Kindly present a copy of this letter to the principal as proof of permission.

I wish you good luck in your research.

Yours faithfully

DR NYATHI NTSIKO
DISTRICT DIRECTOR: PORT ELIZABETH
/ab

10 March 2011

building blocks for growth

PGDP EASTERN CAPE
Ikamva eliqaqambileyo!

Appendix B: Informed consent documentation for parents/guardians

Project Information Statement and consent form for Parents/Guardians

Dear Parent/Guardian

My name is Ayanda Simayi, and I am a Masters' student at the Nelson Mandela Metropolitan University. I am conducting research on Science Education under the supervision of Mrs Elsa Lombard who is a lecturer at NMMU.

The Nelson Mandela Metropolitan University (NMMU) has given its approval for the implementation of the study and the proposed study has met the requirements of the Research Ethics Committee (Human) of the Nelson Mandela Metropolitan University. The School Principal has agreed to allow me to approach learners to participate in the study.

The study has been explained to your child in isiXhosa to ensure that he/she understands clearly what is going to take place. If you have any doubt, please contact me (Ayanda Simayi) by telephone at 084 306 4781 or visit my place of work at Gqebera High School, Missionvale.

I am seeking your consent for your child to participate. I will also seek the assent of your child. Only children who agree and whose parents/guardians consent will participate in the study. I ask that you discuss participation in this study with your child.

The study will be used to determine to what extent an analogy selected to be contextually-relevant to a group of isiXhosa speaking learners and their teachers, can improve their conceptual levels about DC electric circuit concepts

Each participating child will be asked to draw and explain in language of own choice, the size of the electric current which enters and leaves a resistor such as a bulb. This will be followed by an interview with the learners where they will explain their answers to me. Their teachers will receive training by staff of the NMMU in the use of a new teaching strategy. Thereafter, the learners will participate in a lesson taught by their own teachers in their schools. A test will be written by the learners after this lesson to see if there is a change in their understanding of electricity concepts after the use of the new teaching strategy. This will take approximately two teaching periods to complete. The learners are free to withdraw from the project at any time without penalty. All information obtained will be treated in strictest confidence. The learners' names will not be used and individual learners will not be identifiable in any written reports about the study.

A summary report of the findings will be made available to the school. If a learner requires support as a result of their participation in the survey steps can be taken to accommodate this.

Please discuss participation in this project with your child. To give consent for your child to participate, please complete the attached form and return it to the child's teacher.

Thank you for taking the time to read this information. If you consent that your child can participate in this study, would you please sign below and return the form with your child to the school.

Ayanda Simayi	Elsa Lombard
Researcher	Supervisor
NMMU	NMMU

I HEREBY VOLUNTARILY CONSENT TO THE PARTICIPATION OF MY CHILD IN THE ABOVE-MENTIONED PROJECT:		
Signed/confirmed at	on	20
	Signature	

Appendix C: In-depth interview guide for the two teachers

Introducing question

Can you tell me which teaching strategy are you using to teach simple direct current electric circuit concepts to your Grade 8 learners?

Probes:

- *Could you say something more about how you present your lesson?*
- *How do learners respond to you in class after you have presented the lesson?*
- *Can you give a more detailed description of what you do during lesson presentation?*
- *Can you explain what do you do in your class after presenting the lesson?*
- *Do you have further examples of your teaching strategy?*

Specifying question

Can you explain why you are teaching in this way?

Probes:

- *What type of teaching strategy do you use?*
- *Do you use only the selected method in your lessons?*
- *Do the learners seem to understand the lesson?*
- *In which language do you present your lesson? Can you say something more about that?*
- *Which language is used by the learners when responding verbally to you in class?*
- *Which language is used by the learners when writing down assessment tasks?*

Direct question

Do you use pictures and/or stories to teach simple circuit concepts?

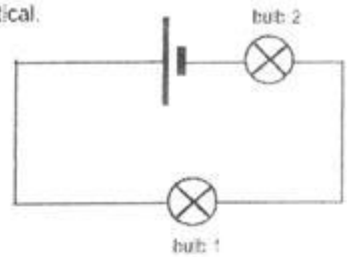
Probes:

- *Why do you use pictures and/ stories?*
- *Do you remember an occasion which you can tell where you used pictures or stories while teaching direct current electric concepts*?

Appendix D: First version of diagnostic test

QUESTION 1: TWO BULBS

The two bulbs in this circuit are identical.



(a) How bright will the bulbs be?

Tick ONE box (✓)

- ☐ Both bulbs are lit. Bulb 1 is brighter than bulb 2.
- ☐ Both bulbs are lit. Bulb 2 is brighter than bulb 1.
- ☐ Both bulbs are lit, with the same brightness.
- ☐ Bulb 1 is lit. Bulb 2 is off.
- ☐ Bulb 2 is lit. Bulb 1 is off.

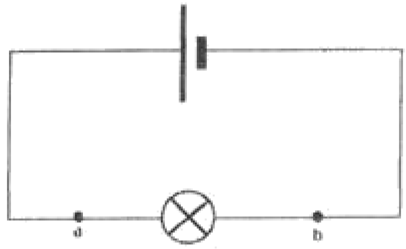
(b) How would you explain this?

Tick ONE box (✓)

- ☐ The first bulb uses up **all** of the electric current, so there is none left for the other one.
- ☐ The first bulb uses up **some** of the electric current, so there is less left for the other one.
- ☐ Bulb 2 is closer to the battery, so it gets more electric current.
- ☐ The electric current is shared equally between the two bulbs.
- ☐ The electric current is the same everywhere in the circuit.

QUESTION 2: CURRENT a and b.

In this circuit, the bulb is lit.



(a) What can you say about the electric current at points **a** and **b**?

Tick ONE box (✓)

- ☐ The electric current at **a** is bigger than at b.
- ☐ The electric current at **b** is bigger than at a.
- ☐ The electric current is the same size at **a** and **b**.

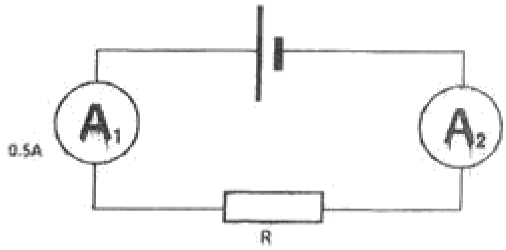
(b) How would you explain this?

Tick ONE box (✓)

- ☐ The current is the same all round the circuit.
- ☐ **Some** of the current is used up by the bulb.
- ☐ **All** of the current is used up by the bulb.

QUESTION 3: RESISTOR AND TWO AMMETERS

In this circuit a battery is connected to a resistor, R.
The reading on ammeter A_1 is 0.5 amps.



(a) What will the reading on ammeter A_2 be?

Tick ONE box (✓)

- ☐ More than 0.5 amps
- ☐ Exactly 0.5 amps
- ☐ Less than 0.5 amps, but not zero
- ☐ Zero

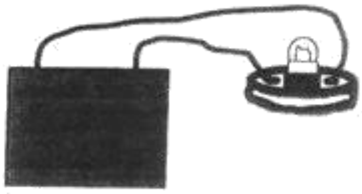
(b) How would you explain this?

Tick ONE box (✓)

- ☐ **Some** of the current is used up by the resistor
- ☐ **All** of the current is used up by the resistor
- ☐ The current is the same all round the circuit

QUESTION 4: FOUR MODELS

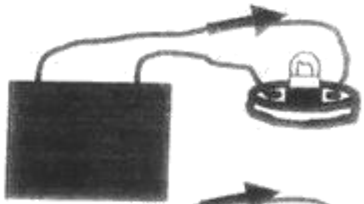
A bulb is connected to a battery. The bulb is lit.



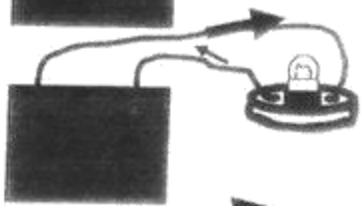
Which of the following best describes the electric current in the circuit?

Tick one box (✓)

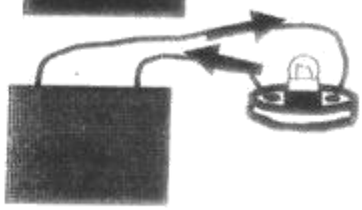
☐ There is an electric current through one wire to the bulb. It is **all** used up in the bulb. So there is no current in the other wire.



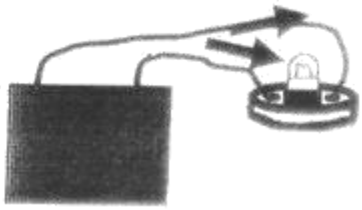
☐ There is an electric current through one wire to the bulb. **Some** of it is used up in the bulb. So there is a **smaller current** in the other wire.



☐ There is an electric current through one wire to the bulb. It passes through the bulb and back to the battery. The current in the other wire is the **same size**.



☐ There are two electric currents from the battery to the bulb. They meet at the bulb and this is what makes it light.

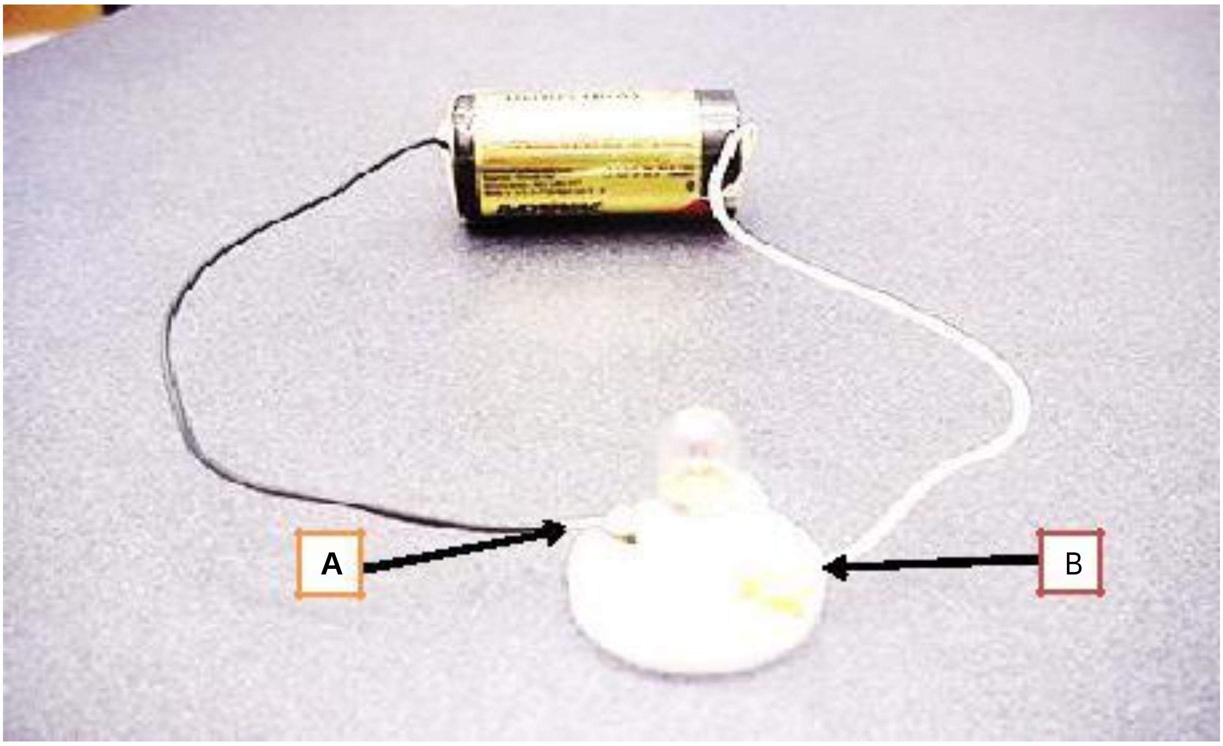


Diagnostic assessments items on circuit diagrams adapted from http://www.york.ac.uk.depts/educ/projs/electricity

Appendix E: Second version of diagnostic test

Below is a picture which consists of a battery connected by two conducting wires to a light bulb. The conducting wires join the light bulb at points A and B. This diagram has been adapted from an image that appears on teachenginnering.com

Answer the following questions by following the instructions given below. **Please note** that this is **NOT** a test but a tool which will be used to get your views about the movement of the



electric current in a closed circuit.

1.1 Use a *blue pen* to draw *two straight lines* to indicate the estimated *size* of the electric current when it reaches point A and point B in the given diagram. Put an *arrow* at the tip of each straight line to show the *direction* of the electric current.

1.2 Do you think that the electric current is *equal or unequal* at different places in a closed circuit? Explain your answer in the language of your choice.

1.3 Do you think that the electric current is moving in the *same direction or at different directions* all around the circuit? Give a reason for your answer in any language that you feel comfortable in.

Appendix F: Abridged Lesson Scheme for teaching lesson on simple circuits using chosen contextually appropriate analogy

Link between the string analogy and content on current electricity	1. **Loop of the string** which goes around and back to the teacher = a **closed circuit** in which the same amount of electric current leaves the battery and goes back to the battery such that the current does not get used up. 2. **Teacher who controls** the movement of the string = **battery**. The string is available in the whole circuit all the time, however; movement will only be initiated when the battery person makes the string to move). Hence, the battery gives the „push‟. 3. **Moving dots** = **flow of charges** (current) which is moving in a closed circuit. This means that all parts of the string are moving at the same rate just like the electric current which is the same everywhere in the series circuit. 4. Holding the **string** firmly = **Bulb** (resistor). 5. **Two people** holding string firmly = resistors **in series.** 6. **Counting** moving dots = **ammeter.**

Appendix G: Post-test diagnostic test instrument selection and understanding of the use of selected analogy by learners

Choice of diagnostic instrument

R: Which picture have you chosen? Is it the one with the symbols for scientific representation in a circuit diagram or the one with a brightly coloured picture of a circuit diagram?

L1: I have chosen the one with the bright colour.

L2: (Pointed at the bright coloured picture).

L3: I chose the one with the picture.

L4: (Pointed at the bright coloured picture).

L5: (Pointed at the colourful picture).

L6: (Pointed at the colourful picture).

Reasons for choice of colourful diagnostic diagram

R: Can you tell me why you chose that one (bright coloured picture) as your answer?

L1: The reason why I did not choose the symbol one because are difficult to identify the batteries and wires because in the symbol one, there are long **wires and small wires** and round bulbs that you don‟t know if it‟s either a battery or a light bulb. So, I use this picture because it‟s clear and you can see the battery and the wires that go through the bulb and go that go throughout the battery again.

L2: It‟s easy to understand because everything is physical. You can see it and you can touch it, you know (batteries and bulbs) from my house.

L3: There are pictures here which show the actual thing, the apparatus used on the particular diagram. That‟s why I‟ve chosen this one, I know the pictures. In your daily lives we use batteries and light bulbs and wires. It‟s more like a vision, you can see it.

R: Your English is so good! (laughter from both researcher and learner).

L5: The colourful picture gives a clear mind about what‟s going on and you can see physically that it‟s a battery and I should know what‟s going on. In symbols, battery is shown by lines and I have to think and figure out what the symbol stands for. But in some in some cases it becomes difficult to come up with a clear name of a symbol but in the picture, everything is clear.

(Le ipicture (colourful) ikunika i-clear mind ukuba what‟s going on and uyazibona izinto physically ukuba it‟s a battery and I should know whats going on. Kwisymbols ibattery yakhona yimigca and so funeka uyicinge lanto ufigurishe out ba yi symbol yantoni le. Kanti ngamanye amaxesha kuba nzima ukuba uthi gqi negama elicacileyo le symbol but ke kuba iyile picture, yonkinto iclear).

L6: It‟s because Miss it (colourful picture) gives a clear understanding than the symbols because symbols are difficult to understand and this one (pointing to colourful picture) is easier.

(Its because Miss it gives a clear understanding than the le yesymbols because le ye symbols zidifficult ukuzi understand and this one is much easier).

R: When you look at the batteries and wires, what is it that makes it easier to understand? Do you know these batteries and wires?

L1: Yes, I do! Cause at home we do use the batteries and the bulbs. We can see the bulbs at home.

L2: It‟s easy to understand because everything is physical. You can see it and you can touch it, you know (batteries and bulbs) from my house.

L6: You see, at home there are lights and you can see a battery. In that symbol circuit, symbol circuit diagram, you don‟t see a battery, you just see a line but in this one, you can see a physical battery and a physical light. (You see emakhayeni ethu there are lights and you can see a battery).

Understanding of selected string analogy

R: What have you understood from the lesson with string analogy with the teacher? If you remember, the teacher gave you first a marked string, this was called a string analogy. What have you understood from that game that the teacher that you did in class?

L2: I understood that the current flows with the same speed and same energy right through to the bulb and from the bulb to the battery. It‶s like a circle.

L3: I think that it will be the same simply because it runs through the same wires so it will remain the same. When it (electric current) reaches the bulb, it goes straight to the bulb which is where it lights the switches and then it also goes back to the battery because it has of it has the flow, the flow of the current.

L4: I understood that the electrical current stays the same and moves in one direction from the battery to the light bulb and then from the light bulb back to the battery but in a one-direction. I think so that the electric current is the same in series no matter what.

L5: It‶s the same because the bulbs don‶t use the whole energy of the battery

R: Ok, so since it‶s a series connection the electric current is the same. So, for this one when the current was entering the light bulb, do you think it is the same or different? I want you to be specific when you explain on when it enters the light bulb and when it leaves on the other side. R: When the electric current goes through the light bulb, what do you understand about the amount of the electric current? Do you think the electric current is going to be the same or is it going to be different at point B? (pointing at the diagram).

L6: "Ok mam. I mean that the electric current comes from the battery through the connecting wires. The energy it uses to flow (in connecting wires) is the same as the energy which it uses to enter the light bulb. Why, because in series connection there is nothing dividing (the current) and no switch dividing too, if it was a parallel connection, there would be a division (switches). Now, in series connection it goes through the battery with the one-energy (same) which it was using through the connecting wires."

("Senditshoba xa isuke kwibatteryini ihamba kwiconnecting wires. La energy ihamba ngayo iyafana nale energy izongena ngayo. Why, because iconnection kwiseries akhonto yahlukanayo and enye iswitch eyahlulelana nayo and ke ngoku, ukuba ibiyiconnection kwiparallel beziza kwahlulelana. Now, kwi series igqitha ibattery ngala energy iyi-one ibihamba ngayo kula connecting wire.")

R: When you say the electric current is the same, does this light bulb use up the current which it receives? Do you believe that the light bulb will use the electric current such that the electric current going out at point B is less? Do you believe that the electric current will be transformed to heat energy or other transformation, what do you think?

L3: I think that it will transform because the light produces heat.

R: I was taking a chance with that question seeing that you are so good in your English (laughter from the learner). Thank you so much.