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EXPLORING STUDENTS' ACADEMIC ACHIEVEMENTS IN ELECTRICITY AND MAGNETISM THROUGH LEARNING STYLES AND LEARNING STYLE-BASED INSTRUCTIONAL STRATEGIES IN MTHATHA HIGH SCHOOLS

by

Sakyiwaa Danso

A thesis submitted to the Wits School of Education, Faculty of Humanities, University of the Witwatersrand in fulfilment of the requirements of the degree of Doctor of Philosophy

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ABSTRACT

This exploratory, descriptive and interpretive study investigated the impact of matching instructional strategies on the learners' learning styles, while considering their cultural background in the teaching of electricity and magnetism among grade 11 learners in schools around Mthatha in South Africa.

To achieve the intended objectives and to answer the research questions, a purposive sample of 245 high school physical sciences learners and five physical sciences teachers were selected for the study from a target population of 1245 physical science learners and 70 physical science teachers in Mthatha district. A pragmatic mixed method explanatory design was adopted for the study. The research instruments included a Physical Science Achievement Test (PSAT), in-depth semi-structured interviews, class observation schedules and Index of Learning Style Questionnaire (ILSQ) adopted from Felder-Silverman Learning Style model. Quantitative data were analysed using descriptive and inferential statistics. Qualitative data were analysed using a constant comparison coding process. The study found that the instructional programmes developed to match learning style preferences effectively improved learner achievement in electricity and magnetism. It is therefore recommended that teachers should use appropriate instructional strategies that would be congruent with the learners' learning styles for effective teaching and learning to take place in the physical science classrooms.

Keywords

Achievements, cultural attributes, electricity and magnetism, instructional strategies, learner achievement, learning styles, learning style-based instructions, performance.

DECLARATION

I declare that this thesis is my own unaided work. It is being submitted for the degree of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other university.



Sakyiwaa Danso

30th day of March in the year 2020.

DEDICATION

I dedicate this thesis to my late father, Mr A.E. Danso. Papa, as we affectionately called you, would have been proud of your last born for this great achievement. Papa, *Damirifa due! Due in amanehunu!*

To God Almighty for given me the strength throughout this study.

To my loving husband and best friend; Albert Kofi Ofosu Boateng, for your encouragement, support and understanding throughout this study.

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PUBLICATIONS AND CONFERENCE PRESENTATIONS EMANATING FROM THIS THESIS

Publications

- (*In prep)* Danso, S. & Mushayikwa E. Exploring effective pedagogies: Aligning teaching and learning styles into the science classroom pedagogies to improve learner success in physical science. *First revision and submitted to the Editor-in-Chief of South African Journal of Education (SAJE).*

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- Danso, S., & Mushayikwa, E. (2017). Exploring students' academic achievements in electricity and magnetism through learning styles and learning style-based instructional strategies in Mthatha high schools. In Proceedings of 3rd International Conference on Education 2017 (ICEDU-2017) (Vol. 3, pp. 64-76).

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- Danso, S. (2018). Fulfilling Diverse Learner Needs: Preparing Learners for High School Science Success through Differentiated Instructions. In A. Jobér, M. Andrée and M. Ideland (Eds.). *Future Educational Challenges from Science and Technology Perspectives*. XVIII IOSTE Symposium Book of Proceeding. (pp. 84-93). Malmö: Malmö University. https://doi.org/10.24834/978-91-7104-971-1.

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- 2019 SAARMSTE Conference (Southern African Association for Research in Mathematics, Science and Technology Education). Oral presentation on *Understanding your learners: developing and implementing learning style-based instructions in a science classroom*. Hosted by University of KwaZulu-Natal. Durban, 15-18th January, 2019.

- 2018 SAERA Conference (South Africa Educational Research Association) Poster presentation on *Alternative to Traditional Physics Instruction: The Effectiveness Of Learning Style-Based Instructional Approach in High School Science Teaching*. Hosted by North-West University, Pretoria, 22-24th October, 2018.

- 2018 Eastern Cape SAASTE Provincial Conference. Oral presentation on *Alternative to Traditional science Instructions: Differentiating instructions to cater for the learner differences in a high school Science classroom*. Hosted by the University of Western Cape Science Centre for Africa. Mthatha, 3-6th October, 2018.

- XVIII Symposium of the International Organization for Sciences and Technology Education. Oral presentation on: *Fulfilling Diverse Learner Needs: Preparing Learners for High School Science Success through Differentiated Instructions.* Malmö, Sweden, August 13-17th, 2018

- 2018 ATINER. Athens Institute for Education and Research. Oral presentation on: *Crossing the Border: Linking Learners Cultural Background Influence on Learning Styles into Physical Sciences Classroom Instructions*. Athens, Greece, 21-24th May, 2018.

- 2018 ICEDU Conference. 4th International Conference on Education. Virtual presentation on: *The use of cooperative instructional strategies to cater for the learning style differences among high school science learners*. Bangkok, Thailand, 5-7th April, 2018.

- 2018 SAARMSTE Conference (Southern African Association for Research in Mathematics, Science and Technology Education). Oral presentation on:

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CHAPTER ONE
INTRODUCTION AND ORIENTATION TO THE STUDY

1.0 Introduction

Physical sciences at secondary school level has become a national priority in South Africa due to the growing awareness about its contributions to the socio-economic and technological development of the nation. According to Ogegbo, Gaigher and Salagaram (2019), as the economic growth is heightened by inventions entrenched in the scientific and technological knowledge applications; the effective teaching of physical sciences becomes very imperative in order to meet the scientific and technological needs of the nation. Hence, the development of programmes to improve scientific literacy is currently an essential endeavour in the South African context. However, according to Muzah (2011) most South African high school learners are relishing above-average levels of educational resources, yet, their success in physical sciences continues to drop. This low achievement of learners in physical sciences over many years manifest in the yearly results from the National Senior Certificate examinations (Department of Basic Education, 2016) where less than 40% of learners achieved above 40%, indicating a lack of well-prepared learners entering fields of Science, Technology, Engineering and Mathematics (STEM) at South African tertiary institutions. In comparison to other nations, findings from Trends in Mathematics and Science Study (TIMSS) reveals that South African learners typically perform below the level expected at the international assessment rankings, as noted by Reddy, Prinsloo, Arends, Visser, Winnaar, Feza, Rogers, Janse, Rensburg, Juan, Mthethwa, Ngema and Maja (2012). According to Even and Tirosh (2008) and Schoenfeld (2011), the role of the teacher in the teaching learning process is deemed necessary and essential factor to address learner poor achievement in the subject. Studies by Alsubaie (2016) and Graham and Fennell (2001) posit that teachers play an essential role in the successful implementation of any curriculum. This is because teachers sift the core curriculum through to their students. It has also been observed by scholars (Ball & Forzani, 2009; Ball, Sleep, Boerst & Bass, 2009; Bansilal & Wallace, 2008) that it is the teachers who make the most important contribution to educational enhancements of their learners.

What is at stake here is the extent to which science teachers' instructions meet the desired

needs of learners learning preferences, as cognitive progressions that contribute to learners' acquisition of knowledge require that in order for learners to solve problems to produce knowledge, leaners need to manipulate ideas and information in their environment. In the learning situation however, every learner has his/her own natural ways of acquiring and processing information. These unique ways are described by Singh, Govil and Rani (2015) as their learning styles.

In literature, numerous learning styles and learning style models exist due to the fact that learning is achieved at different levels. According to Zywno and Waalen (2002), learning style models categorise learners on a number of scales, each measuring the ways learning material is received and processed.

In a similar way, instructional strategies also vary. They include demonstrations, lectures or an emphasis on principles and applications (Felder, 1988). Therefore, how much a learner learns in a classroom is often due to the learners' inherent ability and prior preparation as well as the extent of harmony with the learners' learning styles and their teachers' teaching styles. However, sometimes, mismatches occur and, as a result, some learners may get bored or discouraged and may perform poorly in examinations. In addition to learning and teaching styles as factors influencing individual learning, Vita (2001) identifies cultural background as an essential feature in the advancement of learners' learning. This feature is supported by the fact that culturally-based educational experiences predispose individuals to certain ways of learning. This is reiterated by New York State Board of Regent's Report (1987, as cited in Claxton, 1990, p.3),

> "learning styles and behavioural tendency do exist and that learners from particular socialisation and cultural experiences possess preferences to knowledge that are highly functional in the indigenous home environment and can be capitalised upon to facilitate performance in academic settings".

Knowing each individual learner's cultural background is essential preparation for facilitating and structuring successful instruction for all learners since, as Hewson (1988) has suggested, teaching and learning of science should be sensitive to learners' cultural background by focusing on learners' cognition and affective domain. As such, Guild (1994) recommends the selection of appropriate instructional strategies that match learners' learning style and cultural attributes to facilitate delivery and effective achievement of instructional objectives.

1.1 Background to the study

South African public examinations have consistently played a significant role in the history of the nation's educational system. Historically, they specify clear goals and standards for teachers and candidates, helping to ensure that all schools teach to the same criteria (DBE, 2015). Even though this study focused on grade 11 learners, a closer look at grade 12 annual Matric performances in physical sciences contextualised the problem far more. In the 2015 NSC Examination results for physical sciences, the national pass rate, benchmarked at an achievement level of 30%, dropped from 61.5% in 2014 to 58.6% in 2015. Also, all the nine provinces across South Africa recorded a drop in marks for the subject. According to the DBE (2016), the most alarming decline was in the Eastern Cape Province where the pass rate in physical sciences dropped from 51.8% in 2014 to 45.9% in 2015. In the Mthatha district, the percentage pass rate in the subject dropped from 56.4% in 2014 to 53.8% in 2015. A careful examination at the statistics shows that learners' performances have not been hopeful and as it stands, this is some cause for concern.

Table 1.1: National achievement rates in physical sciences (DBE, 2017)

Year	No. wrote	No. achieved at 30% and above	% achieved at 30% and above	no. achieved at 40% and above	% achieved at 40% and above
2014	167 997	103 348	61.5	62 032	36.9
2015	193 189	113 121	58.6	69 699	36.1
2016	192 710	119 467	62.0	76 068	39.5
2017	179 561	116 862	65.1	75 736	42.2

Some studies in South Africa, for example, Mashile (2001) and Mji and Makgato (2006), explored the major causes that particularly affect learner achievement in physical sciences. They found that, most physical sciences teachers have below the basic levels of science content knowledge and are incapable of answering questions aimed at their learners. They also found that mismatches of teachers' teaching styles and learners' learning styles, among others contributed to learners' poor performance in the subject. In their recommendations, Mji and Makgato (2006) indicate that the recurring poor performance in the subject calls for a concerted effort for measures to improve the status quo.

Mji and Makgato (2006) carried out their study in the Eastern Cape and reported that science

teachers still used out-dated teacher-centred teaching strategies. The writer's own experiences as a science teacher in Mthatha support this observation where traditional teacher-centred instruction emphasises the passive acquisition of knowledge. The bulk of the work, as observed by Zakaria and Iksan (2007), involves teacher-talk, using either a lecture method or a simple question-and-answer technique that basically demands recall of knowledge from the learners. Kulkarni and Klemmer (2012) note that a severe deficiency in traditional teaching methods in the physical sciences resides in the fact that learners do not visualise the details of different science processes and they frequently fail to understand the most basic science concepts and phenomena. Thus, learners are characterised as unreceptive to knowledge and therefore recourse to memorisation. Accordingly, Zakaria and Iksan (2007) posit that these teaching methods are not for conceptual understanding of facts but rather for basic recall of information.

Nevertheless, one of the fundamental principles upon which the National Curriculum Statement (NCS) is based is the relevance of what is being learned. The NCS physical sciences curriculum structures content knowledge into six core areas (DoE, 2003b). These include: mechanics; matter and materials; waves, sound and light; chemical change; chemical systems; and electricity and magnetism (DoE, 2003b). Electricity and magnetism for grade 11 is further sub-divided into sub-sections including: Electrostatics, Electromagnetism and Electric circuits which should be taught for 20 hours in term three. However, electricity and magnetism is one area which learners perceive to be conceptually challenging as it encompasses mental and non-representational phenomena that learners find difficult to grasp as noted by Chabay and Sherwood (2006), Handhika, Cari, Soeparmi and Sunarno (2016), Koba and Mitchell (2011) and Setyani, Cari, Suparmi and Handhika (2017). Some scholars (for example; Guisasola, Michelini, Mossenta, Testa, Viola, & Testa, 2008) have proposed that it is critical for learners to have a solid mastery of the concept of electricity and magnetism, as these concepts form a core knowledge area in the physical sciences curricula worldwide (DBE, 2011a).

Numerous studies have identified difficulties learners experience when learning electricity and magnetism. Bagno and Eylon (1997) found that learners experience difficulties: (1) to master the fundamental ideas in the concepts; (2) comprehending the concepts; and (3) evaluating the association between the central ideas of the concepts to solve problems. In their study, Maloney, O'Kuma, Hieggelke and Van Heuvelen (2001) also identified

difficulties learners experience with electricity and magnetism. These difficulties include: (1) learners' inability to apply both Coulomb's Law and Newton's third law to electric field at a point; (2) learners inability to recognise the effect of new charge on the direction of electric field and force; or (3) learners' inability to recognise and make a distinction between electric field effects and magnetic field effects.

Furio and Guisasola (1998) noted in their study that, concepts of electric fields are nonconcrete, non-representational and have limited resemblances to learners' daily experience. Chambers and Andre (1995) suggest that learners have difficulty mastering the associations of constructs about electric fields and relating it to the consciousness of the direct experiences phenomenological dynamics. This is confirmed by Dede, Salzman, Loftin and Sprague (1999) who state that learners struggle to understand the experience of a test charge in an electric field. This is notwithstanding the fact that these learners cannot visualise the force-effect in an electric field and illustrate how the forces are distributed to explain how the test charge moves in an electric field or even comprehend superposition of "forces-at-a-distance". Dede et al. (1999) also posit the arguments put forward by Bagno and Eylon (1997) that learners struggle to master the basic concepts of electric fields and have misconceptions about Ohms law and the relationships between current, resistance and voltage in a simple electric circuit, as affirmed by Setyani, Cari, Suparmi and Handhika (2017).

In their study about difficulties students' experience in mastering electric fields concepts, Furio and Guisasola (1998) found that learners cannot make a clear distinction between field intensity and electric force, even in situations very familiar within the school context. They further stated that learners' difficulties increase when they are presented with situations of conflicts that require a significant application of the concept of electric field and therefore, the percentage of wrong answers increases. Thus, learners do not take into account the change in the form of electric interactions and continue interpreting them from a Coulombian theoretical basis.

According to the chief markers' report (DBE, 2017), candidates failed to contextualise and identify the series and parallel connections from the graph, which indicates their lack of understanding of these connections in an electric circuit. This report further showed that many candidates could not establish the relationship between resistance, current and potential differences across two points in a circuit.

From the perspective of the researcher as a science educator, for a science teacher to find effective teaching strategies to teach such unobservable and abstract phenomena, specifically involving the use of analogy, in a compelling and comprehensible format, has a meaningful outcome on the removal of misconceptions (Ugur, Dilber, Senpolar, & Duzgun, 2012). According to Dega, Kriek and Mogese (2013), the teacher-centred strategy used in teaching electricity and magnetism does not make learners grasp the content. Nonetheless, challenging and nonconcrete concepts can be successfully taught by means of computer simulations. This method focuses more on using pictorial and graphical representations to explain these concepts (Chabay & Sherwood, 2006).

Froyd and Simpson (2010) advice shifting from a more traditional teacher-centred learning strategy to a more learner-centred strategy that will make the pupils take responsible for their own learning. Since a learning style denotes the learners' natural tendency towards learning, an instructional method, designed with learners' learning styles in mind, could promote individual learning. Burke and Garger (1985) contend that effective educational decisions and practices must derive from an understanding of the ways that individuals learn and for that reason, Landrum and McDuffie (2010) suggest that multiple instructional strategies are necessary to reach individual learners with different learning styles.

The author understands culture as a collective set of traditions, beliefs and behaviours thus phenomena, such as learning and studying, taking place at the level of the learner, are also embedded in a particular culture and reveal common patterns at a macro level. Cultural dimensions, therefore, can be related to the different approaches to learning that could be used by the teachers in their classroom instructions. Barmeyer (2004) and Earley and Ang (2003) suggest that culture influences information dispensation and thought since it acts as an agent of socialisation. Sisco and Kao (2018) affirm the argument that cultural socialisation influences learning preferences and produces different learning styles. This link between learners' cultural background and their learning styles, certainly, is not new. Kolb and Fry (1975) contend that key agents of socialisation, such as the school and the family, are significant means of transferring cultural beliefs and could therefore influence the development of students' learning styles.

Even though much research has been done on learning styles and their determining factors, much less study seems to have been conducted on the learning style preferences among

learners and their association to the entrenched cultural background. There has been even less research on how teachers diversify their instructions to accommodate learners in a culturally diverse setting.

There have been general reports by researchers, for example, Magulod (2019) and Yeung, Read, Robert and Schmid (2006) on how learning styles and teacher instructions affect learners' academic achievements. But these reports do not specify how the subject content of the physical sciences curriculum, together with learners' learning styles, affects physical sciences instructions and consequently learners' academic achievements. There is also limited literature that documents a learning style model specifically designed for physical sciences instructions. Nevertheless, the literature on learning styles (Felder & Silverman, 1988; Kolb, 1984) shows the different learning style models that suggest the application of instructions based on assumptions of learners' differences (Cassidy, 2004). However, many science educators who desire to implement learning style-based instructions in their classrooms teaching are therefore overwhelmed by the enormous literature and therefore are unable to offer correctly, a comprehensive method to teaching.

A careful review of the literature showed that learning styles (Bajraktarevic, Hall, & Fullick, 2003) and instructions (Gohel, 2009) affect student achievement (Orhun, 2012). But these reports are more generalised and do not consider how the structure of the physical sciences curriculum affects learning styles and instructions, and consequently the students' academic performance.

Against this background, the study investigated the impact of matching instructional strategies with the learners' learning styles and cultural backgrounds in the teaching of the topic of electricity and magnetism to grade 11 learners in schools around Mthatha.

1.2 The study context

A careful overview of the South African education policy on inclusive education and the South African physical sciences curriculum put the study into perspective. The current South African education policy promotes a system of inclusivity in schooling. Inclusivity embraces the democratic values of equality and human rights and the recognition of diversity (Engelbrecht, 2006). The Department of Basic Education (DBE, 1999), defines inclusive education, as a warm, embracing attitude that accepts and accommodates human beings

unconditionally, thus promoting the expression of individual differences. Engelbrecht, Green, Naicker and Engelbrecht (1999) postulate that inclusivity also includes the fact that all learners form part of a society and that every learner can learn within his/her own learning style therefore should be accepted in school.

In 1997, the South African government introduced outcomes-based education (OBE) to subdue the curricular divisions of the past, but the experience of execution impelled an urgent review in 2000, leading to the introduction of the new *Revised National Curriculum Statement (RNCS) Grades R-9* and the *National Curriculum Statement Grades (NCS) 10-12* (DoE, 2002).

On-going implementation challenges resulted in another review in 2009, which led to the two national curricula being combined into a single document known as the *National Curriculum Statement Grades R-12.* The new curriculum builds on the previous two curricula but also updates it and provides clearer description of what to teach and to be learnt on weekly, monthly and termly basis. Thus, while the underlying philosophy and content of the curriculum remained unchanged, the fundamental principles of outcomes-based teaching and assessment were dropped. The new curriculum therefore, is more content-based and inclined towards traditional school science as opposed to an inquiry-based curriculum (DoE, 2011a; 2011c).

The *National Curriculum Statement Grades R-12* therefore, comprises the following documents:

a) *Curriculum and Assessment Policy Statements* (CAPS).

b) National policy pertaining to the programme and promotion requirements of the National Curriculum Statement Grades R-12; and

c) National Protocol for Assessment Grades R-12.

Accordingly, the CAPS physical sciences curriculum (grades 10–12), advocates for knowledge and skills in a scientific investigation and problem solving; the construction and application of scientific and technological knowledge; and an appreciative of the nature of science and its interactions. Thus, the teaching and assessment in physical science is broadly guided by the following specific aims:

Specific aim 1 focuses explicitly on making learners aware of their environment and equipping students with scientific skills of investigation physical and chemical concepts. Examples of skills to be developed are: ordering, interacting, designing an investigation, drawing and evaluating conclusions, formulating models, hypothesising, identifying and controlling variables, and inferring, observing and comparing, interpreting, predicting, problem-solving and reflective skills (DoE, 2011b, p. 8).

Specific aim 2 is to promote knowledge and skills in scientific inquiry and problem solving; the construction and application of scientific and technological expertise; and its relations to the technological advancement.

Specific aim 3 is to equip learners for future learning, specialist learning, employment, citizenship, holistic development, socio-economic development and environmental management (DoE, 2011b, p. 8).

For this study, all three specific aims were of interest to the researcher since they relate to learners' understanding of the subject and their achievements in the subject. The skills and processes which learners are expected to use and develop in their study of the physical sciences are enshrined in the new curriculum and therefore, it is the duty of science teachers to design instructional strategies in a way that would encourage learners to observe, analyse, express an opinion, create a hypothesis, look for a solution and discover knowledge by themselves. Teachers' instructional strategies should be planned in a way that aspect of learners' cultural backgrounds are considered, since learners' characteristics are largely shaped by their cultural environment. Keraro and Okere (2009) point out that some of the cultural practices and indigenous knowledge that learners are exposed to may be at variance with conventional science. These socio-cultural predispositions therefore, make a significant contribution to the learning of science.

1.3 Statement of the problem

Several studies, for example, Crawley and Black (1992) and Havard (1996), have identified learners' "perception of physical sciences as a difficult subject". The researcher, being an experienced science teacher has also observed with concern that most learners underperform in physical sciences. Learners generally complain that this subject is too difficult for them to cope with. However, there are undoubtedly many factors that also influence learners studying

physical sciences. Such factors include: a) learners' learning style preferences; b) learners' cultural background; and c) the teacher's instructional strategies. The question is: are these learners underperforming in physical sciences because teacher's teaching approaches do not take into account learners' learning style preferences? Much of my reading on this concept showed that the dullness, lack of interest and thwarting of learners' experiences in the science classroom could be due to incongruity of teaching strategies and learning styles. Therefore, this research project emanated from the need to offer science teachers an alternative approach to teaching to assist their learners to improve upon their performance in physical sciences by aligning instructions to learning style preferences to teach Grade 11 electricity and magnetism. This may provide a precedent for similar research in physical sciences and add to the existing literature on effective instructions in science discipline.

1.4 Summary and the research questions

As suggested in the literature, one way to improve the academic achievement of learners is to identify their preferred or dominant learning styles. Once this has been done, teachers can adapt their teaching to include these particular learning styles. Peterson, Carne and Freear (2011) are of the opinion that this would improve the learners' academic success. Therefore, the study aims to investigate and explore the relationship between learning styles and academic achievement.

The study also addresses a number of sub-problems. One of these sub-problems relates to the cultural attributes of learners found in South African classrooms. If South African teachers want to improve their learners' academic achievements, the teachers need to know whether a particular culture is predisposed to a certain type of learning style. As there appears to be limited research and studies on how learning styles and the learners' cultural attributes are connected, this issue was also examined in the current study.

Given the background to the study, the main research question of the study was:

> What are the relationships among learners' learning style preferences (considering learners' cultural backgrounds), teaching styles, learning style-based instructions and learners' academic achievement in physical sciences among grade 11 learners in Mthatha high schools?

The following sub-questions emanated from the main research question and served to guide

the study:

(1) With regards to the learning style index, what are the prevailing learning styles that are common among these learners?

(2) How can knowledge of the cultural attributes of learning be used to determine the most likely learning style favoured by learners?

(3) What relationships (if any) exist between the teaching styles currently used by the teachers sampled for the study and the most common learning styles of their learners?

(4) What impact, if any, does a learning style-based instruction have on learner academic achievement in physical sciences?

(5) To what extent and in what ways do the learning style-based instructions impact on learners' and teachers' experiences towards teaching and learning?

The research questions 1 and 4 were answered quantitatively. However, research questions 2, 3 and 5 were investigated qualitatively and the findings integrated and discussed.

1.5 The research aim and rationale

1.5.1 The aims of the research

The study aimed to do an empirical investigation to determine the different learning styles of students in the five sampled schools, the role played by their culture, as well as the gender of the students that influence these learning styles. The relationship between learning styles and academic achievement in physical sciences was also explored. The empirical study focused on identifying the learning style that best enhances learners' academic achievements on the topic of electricity and magnetism in the physical sciences curriculum and explored the effectiveness of different learning style-based instructional programmes on students' academic achievements in electricity/magnetism, considering the teachers teaching styles.

1.5.2 The Rationale

The study has the following justifications:

The study implemented a pedagogical model of the subject of physical sciences that integrates learners' cultural attributes, learning styles and learning style-based instructions into the teaching-learning process of the physical sciences curriculum. This is justified because learners have had limited academic success at the sampled schools since the introduction of the NCS Curriculum in 2008. Therefore, an exploration of learning style-based instructions is capable of improving learner achievement in physical sciences education in the high schools. The Felder-Silverman (Felder & Brent, 2005) model used as the theoretical framework for the current study has been successful in improving student performance in higher education. Thus, the study is justified because there is a need to improve student performance in the high schools and the Felder-Silverman model has been implemented successfully on numerous occasions in higher education (Felder & Brent, 2005). The study also tested if this pedagogical model improves the students' academic achievements in the concepts of electricity and magnetism.

If learning styles and learning style-based instructional strategies successfully measure students' academic achievements in the subject of physical sciences, the study would provide empirical evidence about the learning styles and learning style-based instructions that led to better achievement in the subject. Hence, this study will encourage science education researchers to work on pedagogical approaches to physical sciences instructions that will address the learning styles that favour learners' academic achievement.

The study pursued to determine the learning style differences within science classrooms and provide a basis for addressing the individual needs of learners. Thus, this will challenge physical sciences teachers to rethink their instructional strategies to improve their learners' academic achievements. This is vital so that teachers can be made aware of cultures that differ from their own so that they could accommodate the differences learners bring to the classroom. This will ensure that all learners receive equitable instruction that will optimise their learning potential. Thus, this study is capable of providing a methodology to boost the academic achievement of high school science learners at the five sampled schools. Felder (2010), Felder and Brent (2005), and Felder and Henriques (1995) were of the view that, adapting instructions based on learning styles among learners, is necessary because teachers

would continue to teach based on their preferential teaching styles without consideration for students' learning preferences. Findings from the current study have the potential to highlight and even prevent professionals from maintaining the status quo in reference to teaching practices and learning styles. The study would also be capable of attracting attention to the learning styles framework as an effective tool for improving student performance in high schools.

While this study may not provide definitive evidence for the entire learner population of South Africa, it hopes to extend the field for further investigations into learning and teaching styles amongst the South African population and increase awareness of these individual differences within a science classroom context.

1.6 Overview of theoretical framework

Three bodies of theory informed the current investigation. First, the brain-based learning theory which focuses primarily on the brain's function in the learning process (Wilson, 2012) and takes into account the natural and physiological processes that occur during learning. Secondly, the constructivism framework allowed for the exploration of social reality and learning from the individuals' perspective. However, it has become increasingly relevant to educators in all disciplines to identify and address the intellectual desires of students. Lastly, the approaches to learning style theory which centre on the individual's inherent ability to receive and process information in a learning environment (Felder & Silverman, 1988). Numerous studies have been conducted to show that learning style awareness is important and to demonstrate that there are certain measures that are effective in addressing multiple learning styles in the classroom.

1.6.1 Brain-Based Learning Theory

According to McCarthy (2000), there are numerous perspectives with regards to information processing and perception. Hebb (1949) suggests that the two hemispheres of the brain employ diverse approaches while receiving information. This is affirmed by Jensen (2008) who indicates that each hemisphere is rich with nerve cells and contributes its special functions to cognitive, affective and physical activities. Sprenger (2002) believes that the hemispheres spontaneously determine the time spent on thinking about a particular issue and the brain serves its function as a whole.

According to Tileston (2005), the significance of brain-based learning includes making the most of the brain's natural learning processes by diversifying instructions to accommodate learner differences. A study by Nassar (2019) revealed that a brain-based learning approach was effective in improving study habits and relieving test anxiety of learners. Zull (2002) posits that teaching approaches should be central to the art of altering the brain to improve students' study habits. For Kolb and Kolb (2005), meaningful learning does not occur in a single way, but in a unity of circulation because the brain works in a unity while learning. Therefore, based on the findings of neuroscience, Brain-Based Learning guides according to the principles and workings of the brain to improve the best way of learning, increase academic achievement and provide equal opportunities for individual differences.

1.6.2 Constructivism Theory

Social constructivists, for example, Smith (1999), believe that, for learners to apprehend the information clearly and grasp the idea of what is being said in the classroom, they must actively know the concepts for themselves. Learners must be allowed to explore phenomena or ideas, formulate their own hypotheses, share their hypotheses with others and, where necessary, revise their thinking processes using information from their present knowledge.

In addition, constructivism suggests applying teaching methods which force the learner to be an active player. Such methods should encourage the learner to become cognitively engaged in developing a personal understanding of the topic being taught. By so doing, Kapanadze and Eilks (2014) posit that the learner becomes an active thinker, able to interact and collaborate with other learners. Kapanadze and Eilks (2014) also assert that constructivism suggests that learning through interpersonal communication and social interaction is essential for effective learning. This important assertion may be valid, but current research also suggests that helping learners to achieve desired learning outcomes is not just by doing them, but involves a more complex process.

1.6.3 Approaches to learning style models

The Felder-Silverman Learning Styles Model (1988)

Kolb's Learning Style model (Kolb, 1984) and the Felder-Silverman learning style model (Felder & Silverman, 1988) are the two leading learning style assessment tools used in

science and engineering education.

The Felder-Silverman (1988) learning style model recognises that there are multiple dimensions of learning. It characterises them as: “active-reflective”, “sensory-intuitive”, “visual-verbal” and “sequential-global”. These dimensions form continua such that everyone can place themselves along a line from one pole to its opposite. This allows for almost infinite variations in the configurations. The model assigns an individual to one of the four dimensions. This configuration constitutes a learning style profile. Correspondingly, Felder and Silverman (1988) implemented many teaching methods to align with the different learning style. However, Felder (1988) suggests that the quality of science education could be significantly improved if teachers alter their teaching styles to cater for diverse differences among learners in the classroom. At points of learning and teaching style incongruity both students and teachers are discouraged for the reason that learning is not taking place, even though both sides are trying.

1.7 Overview of the methodology

This study employed a mixed methods design in line with the philosophy of pragmatism. According to Denzin and Lincoln (2000) and McMillan and Schumacher (2010), the design combines both qualitative and quantitative methods and thus show both the results obtained, and explain why they were obtained.

According to McMillan and Schumacher (2010), three types of mixed-method designs exist: the explanatory; the exploratory and the triangulation. The researcher for the current study employed the explanatory design (Bogdan & Biklen, 2006; Cohen, Manion & Morrison, 2007; Creswell, 2017) which allowed for the collection of quantitative data, followed by the collection of qualitative data. Accordingly, this design allows for the application of “the strengths of each approach to provide not only a more complete result but also one that was more valid” (p. 28).

1.8 Definitions of key terms

The key terms used in this study are explained below:

Learning: From a cognitivist perspective (Yilmaz, 2011), learning is an active process “involving the acquisition or reorganisation of the cognitive structures through which humans

process and store information" (p. 205). O'Donnell, Reeve and Smith (2012) posit that learning is concerned, not with what students do, but about what learners know and how they come to acquire it. The student is also viewed by cognitivists, for example, Ertmer and Newby (2013), as a very active participant in the learning process.

Learning styles: This is a means by which an individual processes, adopts and internalises different and challenging information. Thus, it influences the way a person thinks, acts, and approaches his/her learning. Learning styles, according to Manee, Nadar and Jahrami (2013), describe the ways in which learners most effectively and efficiently "perceive, process, store and recall material they learn" (p. 255).

Learning style index: It is an instrument used to identify and determine learners' learning style preferences. A learning style index typically takes the form of a questionnaire that focuses on how people prefer to learn.

Teaching Styles: This comprises the principles and methods employed by teachers to facilitate students' learning. According to Felder and Silverman (1988), Teaching styles, refer to teachers' preferential ways of teaching students.

Matching Learning and Teaching Styles: The matching of learning and teaching styles, according to Felder and Silverman (1988), refers to the alignment of teachers' teaching styles with the learning style differences among learners in a science classroom.

Learning style-based instructional strategy: These are different teaching-learning methods, methods and approaches suitable to the learners' learning style preferences in which the teachers' strategies are designed with the focus on learners' learning style profiles.

Instructional strategies: These are teaching styles and methods employed by the teachers in their classroom practices to deliver lesson to the learners.

Academic achievement: Academic achievement refers to the achievement levels of students in all academic content areas (e.g., physical sciences, mathematics, etc.) as indicated by results of a standardised achievement test.

Standardised achievement tests: Ary, Jacobs, Razavieh and Sorensen (2006) define standardised tests as any tests "with specific content, prescribed directions for administering and scoring, norms, and reliability and validity information derived from administration to

representative samples" (p. 639).

1.9 Assumptions and Delimitations

1.9.1 Assumptions

Three assumptions are associated with this study. The first assumption is the belief that it is possible to adapt instructional methodology with students' preferred learning styles in a classroom. Many researchers and educators, for example, Chermahini, Ghanbari and Talab (2013), concur that teachers should identify students' learning styles and adjust teaching strategies to address the need of each student. The second assumption pertains to the notion that students perform better in school when their learning styles are in alignment with teachers' teaching styles. Proponents of the learning-style model (Felder & Silverman, 1988; Kyprianidou, Demetriadis, Tsiatsos, & Pombortsis, 2012; Tulbure, 2012) believe that congruence between teaching and learning styles is an effective pedagogical approach designed by best practice. Lastly, this study employs the Felder-Silverman Index of Learning Style Instrument. It is assumed that the Felder-Silverman learning style instrument reasonably assesses the learning styles of learners. Although this instrument has undergone reliability and constructs validity testing in several engineering education contexts, no such study has been conducted in a physical sciences setting. Thus, it is assumed that the instrument is equally effective across all learning style categories. This assumption was addressed in the data analysis phase by comparing reliability measures across learning style categories.

1.9.2 Delimitations of the Study

Because of the strengths associated with the current study, there were a few limitations. The research participants for the current study consisted of approximately 245 grade 11 physical sciences learners and five science teachers from five schools in Mthatha, Eastern Cape. These respondents were selected due to the proximity of the location around the researcher's school. Lund (2012) suggests that critics might be tempted to question the legitimacy of a study when a small sample size is used.

All respondents who signed and returned the consent authorisation forms during the initial survey introduction sessions were included in the study. The researcher did not select any respondent based on gender, ethnicity or any other demographic categorisation.

Learning style-based instructional programmes were developed by the researcher. The quality of research supporting the learning styles framework as an effective tool for improving student performance continues to be questioned by critics. Many critics (Coffield, Moseley, Hall, & Ecclestone, 2004; Pashler, McDaniel, Rohrer, & Bjork, 2009) argue that there is limited methodologically sound research to substantiate the alleged benefits of aligning teaching styles with students' learning styles. Emphasis was placed on acquiring adequate evidence to promote credibility and transferability with the findings from the current study.

Although there are different learning style models, the study was limited to the Felder-Silverman learning style model which was considered as a pedagogical model for the current study. The structure of the Index of Learning Style (ILS) questionnaire presented another limitation for the study. Students' learning styles were generated after they had answered 44 questions, by selecting one of two possible answers for each question, according to Felder and Brent (2005) and Felder and Silverman (1988). The legitimacy of the instrument could be questioned based on the forced-choice nature of the answer-selection process as participants were forced to select one of two possible answers, in spite of the irony attached to the model emphasising diversity in learning styles.

1.10 The Thesis chapter overview

This section gives a summary of the focus of each of the chapters in this thesis.

Chapter One: Introducing the study and the study overview

This chapter introduces the study and gives an overview of the whole thesis. The research problem-purpose statement is articulated. The study background and the rationale for the study are explicated and the knowledge gap is identified which was used to locate this study in the bigger debate locally and internationally on learning styles and their impact on learner performances in physical sciences.

Chapter Two: The literature review and the theoretical frameworks

This chapter explores and discusses major studies that have been done so far locally and internationally on each of the main concepts: learning styles, learning style-based instructions, culture and learner achievement in physical sciences, as well as the various perspectives of theories of learning styles and teaching styles that may impact on learner

achievement in physical sciences. Thus, the work of scholars, such as Felder-Silverman, on learning styles and instructional strategies, the social constructivism theory and cultural border crossing are explicated.

Chapter Three: Research design and methodology

The chapter elaborates the research paradigm that underpins the research methodology. The rationale for a methodological choice of this study is made apparent. An exploration into the methodological framework capturing the research design is explicated. Data collection instruments and data collection framework used in this study are explained and justified. Furthermore, an analysis of quantitative and qualitative data frameworks are described and justified in this chapter.

Chapter Four: The development of learning style-based instructional programmes

This chapter discusses the development of "learning style-based instructional programmes". It discusses the utilisation of different instructional strategies, based on learners' learning style preferences that could be used by the science teachers to improve learner performance in the subject.

Chapter Five: Data analysis tools and data summaries

This chapter focuses on the validation of research instruments which were adopted (index of learning style questionnaire) and developed (physical sciences achievement test) for this study. The validations of the instruments were based on the quantitative data collected from the learners from the sampled schools. Multiple regression analysis was used to investigate the criteria and construct validity of the instruments. The chapter also gives a brief overview of the data forms and present summaries of observations and interviews and provides interpretation of the results in terms of instructional strategies and learner achievements.

Chapter Six: Cultural attributes of learning style preferences

This chapter is the second which engages with the research findings. The chapter discusses the data analysis relating to the second research question: "How can knowledge of the cultural attributes of learning are used to determine the most likely learning style favoured by learners?" Therefore, the descriptions of results of learners are discussed in the light of findings from related literature.

Chapter Seven: Learning style-based instructions on academic achievement of learners

This chapter provides the description of results of the learners' and teachers' conceptions about learning style-based instructions through the presentation of qualitative analysis of the study research sub-question: "How can students' academic achievements in electricity and magnetism be explained by the use of learning style-based instructional strategies in the science classroom?" Learners and teachers responses were analysed using thematic analysis framework. Problems encountered during the coding process are explained in the chapter.

Chapter Eight: Discussion: Exploring interactions among the three investigated variables

This chapter discusses the findings from the research questionnaires and the interplay between the three variables of the study and focuses on the main research question that guided the study which is:

> What is the relationship between learners' learning style preferences (considering learners' cultural backgrounds), learning style-based instructions and learners' academic achievement in physical sciences among grade 11 learners in Mthatha high schools?

This was made possible to explicate possible relationships between learning styles, learners' cultural background and learners' academic performance in electricity and magnetism. The diverse methodological framework used provided the exploration of possible relationships between the variables, which were then discussed in the light of findings from related studies.

Chapter Nine: Summary, findings and conclusions

The chapter discusses the summary of the key findings and conclusions of the thesis. The results discussed in the previous chapters are interwoven and substantiation is revealed from the exploration of the key variables of the study. Recommendations and areas of future research coming out of this study are provided and highlights of the study limitations are given.

Chapter Summary

This chapter provides a brief contextualisation of the study in terms of the problem statements and knowledge gaps as well as how the study addressed the problem. The chapter also provides an overview of the purpose of the study explains the research questions and provides

the operational definition of core concepts. It outlines the review of the relevant literature, covering learning style preferences and their influence on learner academic background, as well as the theoretical lenses that guided the current study.

CHAPTER TWO
LITERATURE REVIEW AND THE THEORETICAL FRAMEWORK

2.0 Introduction

A review of related studies is an essential requirement of the planning and implementation of any research work. The accessibility and use of passable sources of literature enabled the researcher to have perfect insight into the study area to conduct the study successfully. Since the problem under investigation is "exploring students' academic achievements in electricity and magnetism through learning styles and learning style-based instructional materials in Mthatha schools", the researcher tried to collect literature corresponding to learning styles, culture, learning style-based instructional strategies, the achievement of learners in physical sciences as well as related variables relevant for the study. Thus, the review has been divided into sub-sections.

2.1 Defining and conceptualising learning styles

The literature offers a countless of definitions of learning style. As suggested by Vita (2001), the one which, by virtue of its encompassing properties, still commands benchmarking significance, is that provided by Keefe (1979, p. 4), that "learning styles are characteristic cognitive, effective, and psychological behaviours that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment". Gregorc (1979) describes learning style in a similar way; as distinctive expressions which serve as indicators of how a person receives and process information in a learning environment. According to Kolb (1984), learning style is the "generalized differences in learning orientation based on the degree to which people emphasize the modes of the learning process" (p. 76). Similarly, Dunn and Dunn (1993) define learning style as the method of integrating the information available to them during the process of learning. Schmeck (2013) also defines learning style as being the cognitive style that a person demonstrates or manifests when confronted with a learning task that includes concepts that incorporate individual motives and personal experiences that influence perception.

Learning style (LS), according to Kyllonen and Shute (1989), is the characteristic way an individual likes to go about learning. Even though there are features of learning styles that are

steady in an individual across different learning tasks and contexts, Smith and Dalton (2005) affirm that there can still be variation in the same learner. De Bello (1989) defined the concept as being the way in which an individual pursuits meaning. Hill (1976) considers cultural determinants to have great value in the learning process. If students become aware of their learning styles and strategies, they are not only more prepared for learning, but also more analytical about their learning styles and the strategies they use to learn. Farajolahi and Nimvari (2014) suggest that information about one's own learning style is essential in "learning to learn" as it enables students to take control of their learning whilst still allowing them to maximise their potential for learning (p. 159). Therefore, learning styles, according to Tuan (2011), can be seen to be students' comfort zones or the educational conditions under which they learn best (p. 287).

Learning styles, according to Reid (2005), overlap with other important aspects of learning, such as learning theories, learning strategies, intellectual styles, thinking styles, multiple intelligences, cognitive styles, metacognition types and teaching styles. Learning styles are often added to the concept of learning strategies.

From these definitions, I argue that each learner has a distinctive approach of receiving and processing experiences and information. The differing definitions have begat the myriad of models, instruments or schemes used to categorise learning styles, and hence, no single commonly accepted scale currently exists, even though several potential scales and classifications are in use. Many of these models focus on relatively narrow aspects of learning styles such as a preference for visual input. Others are far more elaborate and focus on factors associated with personality issues. Some learning style models, according to Coffield et al. (2004), Daghani and Akkoyunlu (2012), Reid (2005) and Slavin (2009), attempt to identify how individuals process information in terms of cognitive style and others emphasise the body's role in learning. Some models view learning styles as being stable and influenced by inherited traits, whilst others are the consequence of the changes that is established between self and the learning environment. Kablan and Kaya (2013) claim that learning styles are flexible and influenced by motivational and environmental factors. Each model therefore has its own definition of learning style.

2.1.1 Variations in definitions and exploration of learning styles

Though widespread agreement supports the existence of individual differences, learning style researchers often define the concept differently. Thus, there is confusion of definitions of learning styles concept and extensive discrepancies in scale of instruments claimed to be predicted by learning style models. The evidence gathered to support various definitions differs profoundly in terms of psychometric standards. Opposing ideas about learning styles have led to a creation of terms and concepts, a most of which were used exchange ably in learning styles research, for example, "*learning styles*", "*learning strategies*" and "*approaches to learning*", "*cognitive* styles" and "*thinking styles*". Nonetheless, the opposing theories and tools of assessing them, and the efficiency of such measures are so different that simple choices about the most suitable are hard to validate. Different ideas about learning styles create distinctive approaches to identifying the specific attitudes and skills that characterise learning styles.

Lovelace (2005) and Pashler et al. (2009) were of the view that much of the work on learning styles has been dedicated to defining learning styles and proving that differences exist in the preferred styles of individuals. Although these researchers seem to be writing on different characteristics, a closer look reveals that the models overlap in many ways. For example, some studies (Denig, 2004; Young, 2002) focus on identifying classification schemes and asserting their significance for education. Others (Felder & Brent, 2005; Hall & Moseley, 2005; Wilson, 2011) provide an overview of various models and attempt to provide an amalgamated view of several approaches.

Kolb (1981) suggests that learning is inherited, while Dunn and Dunn (1978) indicate no relationship between the learning styles of children and their parents or siblings. Gregorc (1979) advocates for selective teaching of learners to build upon their weaker characteristics, while Dunn and Dunn (1978) insist that traits develop over time and that learner should always be taught through their strengths. Dunn and Dunn (1978) however indicated that learning style characteristics can be divided into "factors" and "preferences" suggesting that factors tend to be relatively stable over time, while preferences can be overcome by motivation or interest.

From the range of definitions of learning styles, the following assumptions can be drawn:

- Learning styles are personal and different;
- Learning styles are context driven;
- Learning styles encompass information processing;
- Learning styles involve interacting with new and difficult information;
- Learning styles encompass attitudes towards learning and the learning environment;
- Learning styles are dynamic and depend on the task at hand.

In order to identify learning styles, various learning style models have been developed. These models have their own theoretical bases and make use of learning style instruments which contain questionnaires designed to help individuals to evaluate their best ways of learning.

2.1.2 The classification of learning style models

The various ways in which people receive and process information in a learning environment has been characterised by a variety of theoretical learning style models (Cassidy, 2004). Therefore, learning style models classify learners according to where they fit on a number of scales pertaining to the ways they receive and process information.

Academic scholars have tried to classify the extensive range of learning style models that exist. According to Hall and Moseley (2005), even though many of these models share some characteristics, each has a distinctive viewpoint, focusing on learners' abilities and preferences. These diverse viewpoints share an underlying justification that not everyone can be taught in the same way.

Aliakbari and Qasemi (2012) indicate in their research that there are at least 100 learning style models and instruments with much conceptual overlap among them. These learning style models are important to explain students' preferred way of learning and how they influence students' academic achievement. One such model is the Curry "Onion" model (Curry, 1983; 1987) (see Figure 2.1 below) that is a standard method of classifying learning style models, which categorises learners' learning differences as four layers of an onion: instructional preferences, social interaction preferences, information processing and personality levels.

The outermost and the most observable layer comprise instructional preferences which focus

on the individuals' choice of environment in which to learn. Gordon and Bull (2004) believe that the outermost layer relates unswervingly with the environment in which the learner learns, learner anticipations, teacher expectations and other peripheral features, and influences the level of measurement in the learning styles arena. The Dunn and Dunn model (1993) and Rezler (2013) learning style are assigned under this cluster.

Social interaction forms the subsequent layer and deals with the individual's preference for social interaction during learning. The focus is on the capability of learners to cooperate with their peers in the learning process. The layer focuses on the differences among learners with regards to age, gender, or levels of maturation. Examples of this type of model are the Grasha (1975) and the Reichmann (1974) LS models.

The third and the more stable layer, according to Gordon and Bull (2004), encompasses an information processing model which is conceived of as the individual's intellectual approach to obtaining, sorting, storing and utilising information. Learning style models, such as Felder and Silverman (1988) learning styles, KoIb (1981) learning styles, and Schmeck, Ribich and Ramanaiah (1977) LS models fall under this category.

The innermost layer encompasses Cognitive Personality Style. This is an underlying and relatively permanent personality trait which can shape and influence a learner's ability to acquire and integrate information. Cuthbert (2005) suggests that the Myers-Briggs Type Indicator (MBTI) is based on personality levels.

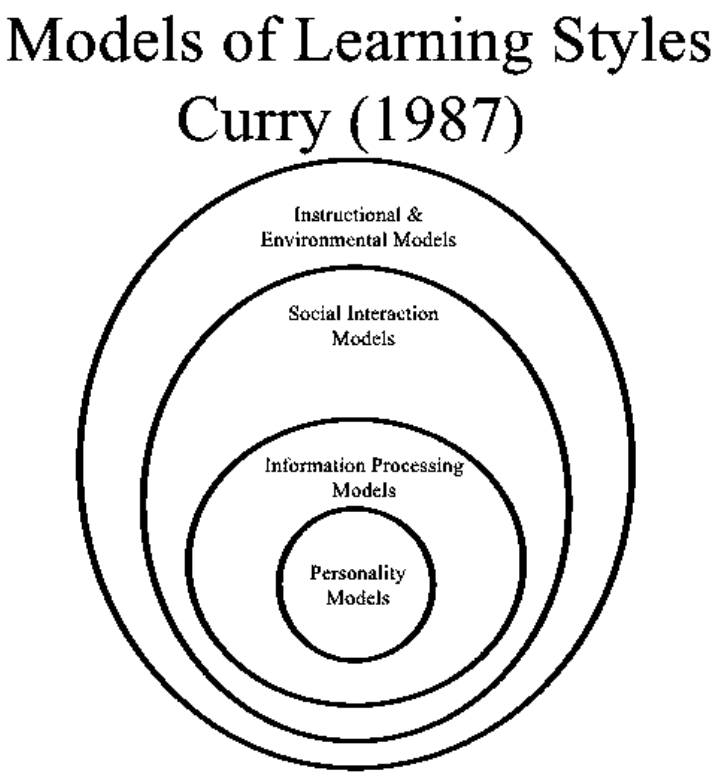


Figure 2.1: Curry Onion model of learning style (1987)
Source: Adapted from Eagleton and Muller (2011)

Ellis (2001) provides a similar interpretation of how learning style models could be classified as seen in Table 2.1 below.

Table 2.1: Classification of learning style models
Source: Adapted from Ellis (2001, p. 150)

CATEGORY	CHARACTERISTICS	THEORISTS
Cognitive – perceiving, finding out, obtaining information	Sensing/Intuition	Jung, Myers-Brigg, Mok, Keirsey and Bates
	Field dependent/Field independent, Abstract/Concrete	Witkin, Gregorc, Kolb and McCarthy
	Visual, Auditory, Kinaesthetic/Tactile	Barbe and Swassing; Dunn and Dunn
Conceptualisation – thinking, forming ideas, processing, memory	Extrovert and Introvert	Jung, Myers-Brigg, Keirsey and Bates
	Reflective Observation/Active Experimentation	Kolb and McCarthy
	Random/Sequential	Gregorc
Affect – feelings, emotional responses, motivation, values, judgements	Feeler/Thinker	Jung, Myers-Brigg, Mok, Keirsey and Bates
	Effect of temperature, light, food, time of day, sound, design	Dunn and Dunn

Looking at the analysis of the Curry "Onion" model (1983; 1987) and Ellis's (2001) classification of learning style models, the researcher selected the learning style models designed by Felder and Silverman (1988), Gregorc (1979) and Kolb (1984), provided an in-depth discussion on each one of the models to provide an overview of learning style classifications. The researcher provided a more detailed account on the Felder-Silverman learning style model as parts of this model were used in the design of the questionnaires for this study.

Kolb's learning style model and the implications for science learning

Kolb's (1984) model of learning styles is an experiential learning model linked to the personality of the learner. The initial ideas for Kolb's model were drawn from the work of Piaget (1952). Kolb's (1984) model defines learning style as the; "generalized differences in learning orientation based on the degree to which people emphasize the modes of the learning

process" (p. 76). According to Kolb, a learning style is not a characteristic which is permanent, but a variance inclination towards a particular way of processing information which changes marginally from situation to situation. Kolb also views learning as a general set of continuous processes with less emphasis being placed on outcomes.

In the early 1970s, Kolb's theory of experiential learning and the instrument which he developed to test the theory, the Learning Style Inventory (LSI), spawned a huge body of research. Kolb (1984) was disgruntled with the traditional teaching methods implemented by most educators. He therefore experimented on his experiential teaching methods. During this process, he observed that some students had certain preferences for some activities (such as aerobics), but not others. The idea of an inventory that would recognise preferences for learning by capturing individual learning differences, as suggested by Coffield et al. (2004), developed from these observations. Kolb designed and later advanced the inventory into a self-report LSI which was used to assess learning styles derived from his experiential learning theory.

Kolb's model asserts a four-stage cycle, with learners having additional experiences, reflecting on them, deducing generalisations about the experiences, and then using them as guides to further action at increasing levels of complexity. Kolb's immediate concrete experience is the basis for observation and reflection which is assimilated and distilled into a new abstract concept (generalisation) that will be accommodated and ready for action and active experimentation. At each stage of the situation, students develop a tendency to some preference (referred as learning styles) over others. In this way, Kolb (2000) arrived at four primary learning styles (p. 5).

Type 1: the Converging style: is centred on abstraction and active learning, which focuses on abstract conceptualisation and active experimentation (i.e. AC + AE). Such learners are more focused, use deductive reasoning and a single solution oriented problem solving approach, appear to be unemotional and enjoy science subjects. They are good at problem solving, decision making, the practical application of ideas, conventional intelligence tests and prefer dealing with technical difficulties.

Type 2: the Diverging style: is centred on the concrete and reflective learning with emphasise on concrete experience and reflective observation (i.e. RO + CE) (Garnett, 2005). Divergers prefer to see situations from different perspectives, brain storm, tend to be imaginative,

emotional, innovative, social/art loving and are aware of meanings and values. Concrete situations are seen from many perspectives and that observation is adopted rather than action.

Type 3: the Assimilating style is centred on abstract and reflective learning which prefers abstract conceptualisation and reflective observation (i.e. RO + AC). Assimilators prefer to learn through inductive reasoning and like abstract concepts more than people and/or concrete experiences. Thus, they prefer to learn mathematics and science, like to reason inductively and to create theoretical models. They are more concerned with ideas and abstract concepts.

Type 4: the Accommodating style: is centred on concrete and active learning which emphasise on concrete experience and active experimentation (i.e. AE + CE). Accommodators learn best by doing things, carrying out plans, performing experiments and have concrete experiences and social interactions. They like doing things, carrying out plans and getting involved in new experiences. However, the most outstanding strengths of students with this type of learning style are practicality, leadership and the courage to take risks (Bennett, 2013; Duman, 2010; Yilmaz-Soylu & Akkoyunlu, 2009).

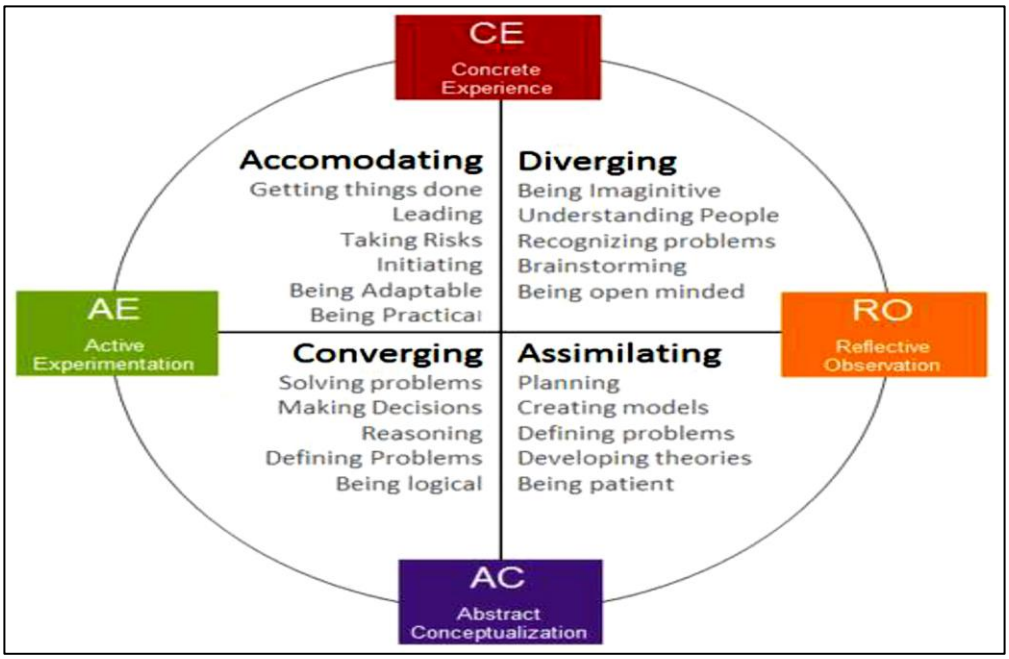


Figure 2.2: Kolb's experiential learning style model
Source: Adapted from Barmeyer (2004)

According to Kolb (1984), depending on the individual's preferences, learning may start at

any one of the other modes in the cycle. Hence, for Kolb (1984), a particular task or environment may be particularly fertile for enhancing one or another generic adaptive competence. An individual expands his/her learning and adaptive processes through exercising them. To measure the learning styles of an individual, Kolb and his colleagues developed the Learning Style Inventory. The Kolb model has many advantages. JilardiDamavandi, Mahyuddin, Elias, Daud and Shabani (2011) assert that the questionnaire is relatively simple to administer and score and it has demonstrated a high degree of reliability. According to Aliakbari and Qasemi (2012), it is the most researched, critiqued and replicated of the myriad of LSIs.

Assertions that the learning style model outlined by Kolb is associated with learner's performance have been borne out in a number of studies. Some studies (Malcom, 2009) show academic performance privileges for converging and assimilation learning styles. Cagiltay (2008) study shows that most assimilator and converger engineering students performed better than accommodators and divergers. Cagiltay (2008) further shows that the ANOVA and "post hoc comparisons using the Dunnett's C-test" showed that only assimilators' and divergers' academic performance scores were statistically significant (p. 420). Similarly, Hargrove, Wheatland, Ding and Brown (2008) report in their study that convergers achieved a higher GPA than divergers when learning style was compared with academic performance.

Kolb's model does not escape criticism. Manikutty, Anuradha and Hansen (2007) find that the model does not lend itself to theorising about how Kolb's learning styles could vary across cultures. In addition, Greenaway (2006) has identified a number of weaknesses inherent in this model. A key issue concerns both reliability and validity of the learning style instrument. In their review, Coffield et al. (2004) contend that, if Wierstra and DeJong's (2002) analysis, which reduces Kolb's model into a basic bipolar tool of reflection as opposed to doing, proves to be correct, then the notion of a learning cycle may be completely inconsistent. However, Kolb's model has also been criticised by Williams, Brown and Etherington (2013) for being too complex.

Gregorc's learning style model

Gregorc's (1979) model is grounded on phenomenological research as well as Kolb's experiential learning style, that defines learning style as "distinctive and observable behaviours that provide clues about mediation abilities of individuals and how their minds

relate to the world and, therefore, how they learn" (Gregorc,1979, p.19). Gregorc's Mind Styles Model is metaphysical in which minds interact with their environments through "channels", the four most important of which are measured by the Gregorc Style Delineator as affirmed by Hawk and Shah (2007). Gregorc suggest that individuals perceive the world in both material and immaterial ways and subsequently order those perceptions in either a sequential or random fashion. The combination of these perceptual abilities and ordering abilities produces four combinations: Concrete Sequential, Abstract Random, Abstract Sequential and Concrete Random. Although both of the perceptual abilities and ordering abilities are found in each individual, some will be more controlling in an individual. It is this combination that defines our preferred Mind Style and offers the foundation for our specific learning styles.

Gregorc's model (1984) has two perceptual abilities: (a) concrete and (b) abstract, and two ordering abilities: (a) random and (b) sequential. Concrete perceptions encompass recording information through the five senses, while abstract perceptions comprise the understanding of thoughts, abilities, and notions which cannot be seen. Regarding the two ordering abilities, the sequential feature comprises the organisation of material in a linear, logical means and random includes the organisation of material in pieces and in no specific order. Both the perceptual abilities and the ordering abilities are present in each individual, but some perceptual abilities and ordering abilities are more controlling within certain individuals.

There are four combinations of perceptual abilities and ordering abilities based on domination: a) Concrete Sequential; b) Abstract Random; c) Abstract Sequential; and d) Concrete Random. People with diverse blends learn in various circumstances; they have different strengths and weaknesses they ask different questions throughout the learning process.

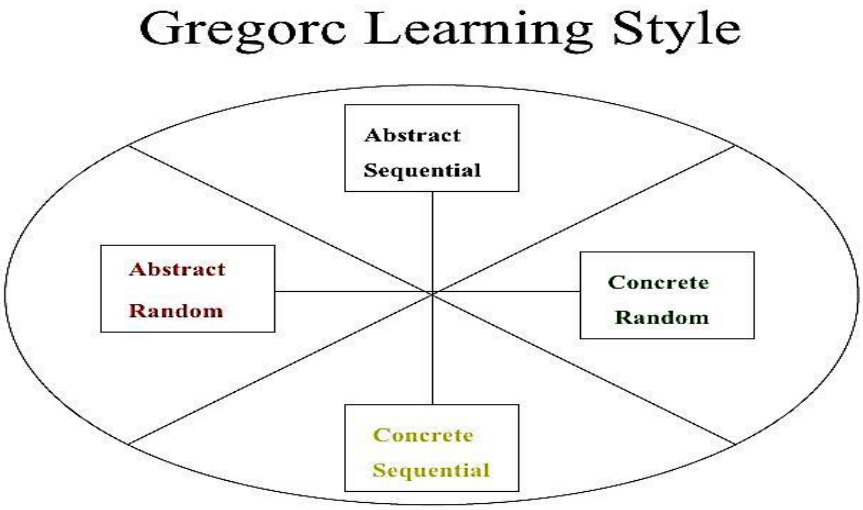


Figure 2.3: Gregorc learning style model
Source: Adapted from Gordon and Bull (2004).

The Gregorc Style Delineator (GSD) tool proposes a measure of perception and ordering, and assigning an individual a score in each of the four LS, namely; Concrete-Sequential (CS), Abstract-Sequential (AS), Abstract-Random (AR) and Concrete-Random (CR) (Hawk & Shah, 2007). Gregorc describes the constructs *concrete* and *abstract* as orthogonal to *sequential* and *random*.

Gregorc's four styles can be summarised as follows (Gregorc, 1982a; Hawk & Shah, 2007):

- The concrete sequential (CS).
- The abstract sequential (AS).
- The abstract random (AR).
- The concrete random learner (CR).

Gregorc (2002) highlighted that every learner can make use of all four channels of the Gregorc's learning style but, according to Gregorc (2002), there are intuitive dispositions towards one or two of the channels. Gregorc argues that well defined LS preferences are interconnected with preferences for definite instructions and teaching strategies, and acknowledges that most people prefer instructional diversity in a particular subject. Gregorc

advised teachers to use such a learning style tool when adapting instructions. Students were also advised to work with their strong preferences and to keep away from activities for which they have low preferences. Students with high or low preferences can adjust to different teaching styles. Gregorc argues against efforts to force teachers and students to change their inborn styles. According to Coffield et al. (2004), Gregorc believes that this will do more harm than good and will estrange people. Seidel and England's (1999) study found some evidence to support some of Gregorc's claims. Amongst the 64 students out of 100 students displaying a clear preference for a single cognitive style, a sequential processing preference was considerably related to a preference for organised learning and activities, together with independent lab work.

Despite the advantages of Gregorc's learning style instruments, they have been criticised by scholars. Coffield et al. (2004) did not find any published evidence addressing the benefits of self-knowledge of learning styles or the alignment of Gregorc-type learning and teaching styles. Lundstrom and Martin (1986) study did not find any evidence to support their extrapolations that C S students would respond better to self-study materials and AR students to discussions. There is no empirical evidence for construct validity other than the fact that the 40 words were chosen by 60 adults as being expressive of the four styles. Gregorc makes the unsubstantiated claim that students who ignore or work against their style may harm themselves. Coffield et al. (2004) conclude that "the GSD is theoretically and psychometrically flawed and is not suitable for the assessment of individuals" (p. 19).

2.2 Felder-Silverman learning style model

In 1988, Felder and Silverman developed a learning style model. This model, according to Hawk and Shah (2007), defined learning style "as the characteristics, strengths and preferences in the ways individuals take in and process information" (Felder & Silverman, 1988, p. 674). The model was designed to capture the most important learning style differences amongst engineering students. It was believed that this model would provide a good basis for engineering lecturers to plan a teaching method that would cater for the learning desires of all students (Bosman, 2015). It was also assumed that students differ in terms of the learning styles and learning strategies that they use. Therefore, according to Dahlan, Noor, Mustafa, Hashim and Zulkifli (2010), awareness of these learning styles and teaching strategies would be essential for both students and teachers to get the most out of the

lesson.

The Felder-Silverman Learning Style (FSLS) model (1988) categorises the learners' learning style preferences in a scale of four dimensions. Each student's learning style may be defined in large part by the answers to the five questions (p.675):

- What kind of information does the student preferentially perceive: *sensory* (external) - sights, sounds, physical sensations, or *intuitive* (internal) - possibilities, insights, hunches?

- Through which sensory channel is external information most effectively perceived: *visual* – pictures, diagrams, graphs, demonstrations or *auditory* - *words*, sounds? (Other sensory channels – touch, taste, and smell – are relatively unimportant in most educational environments and will not be considered here).

- With which organisation of information is the student most comfortable: *inductive* – *facts* and observations are given, underlying principles are inferred or *deductive* – principles are given, consequences and applications are deduced?

- How does the student prefer to process information: *actively* - through engagement in physical activities or discussion, or *reflexively* - through introspection?

- How does the student progress: towards understanding: *sequentially* - *in* continual steps, or *globally* – in large jumps, holistically? (Felder & Silverman, 1988, p.675).

The four dimensions in FSLS model (Table 2.2) categorise learners under each dimension. The first dimension is the sensing-intuitive learning style (LS). Sensing learners learn from realities and physical materials. They are mostly problem solvers and solve problems systematically and are likely to be enduring on task. They are precise and practical. However, intuitive learners prefer to learn non-representative material, such as concepts and their causal significances. They are more able to discern prospects and associations and tend to be inventive and ingenious than sensing learners.

The second dimension, the visual-verbal LS, distinguishes between learners who learn particularly from what they see (e.g., pictures, diagrams and flow-charts), and learners who learn from word-based representations, either it is spoken or written.

The third dimension differentiates between active and reflective LS. Active learners learn by active participation with the learning material, experimenting with the material and communicating their observations to their peer. They also learn actively in groups where they discuss the learning material. In contrast, reflective learners prefer to deliberate about the learned material and reflect on the content. They also desire to work as individuals or perhaps in a small group together with their friends.

In the fourth dimension, the learners are categorised according to their understanding on the learned material. Sequential learners, therefore, learn in gradual leaps and work systematically to find answers to solutions. In contrast, global learners employ all rounded thought provoking process and learn in large leaps. They tend to process information randomly without knowing relations but, after they have learned adequate material, they abruptly get the whole picture. Then they can solve complex problems, find associates between different concepts. Because the whole concept is important for global learners, they tend to be concerned in summaries, whereas sequential learners are concerned with specifics. The table below shows the learning style dimensions that resulted from the latter questions.

Table 2.2: Felder-Silverman learning style model (Felder & Silverman, 1988)

Learning style dimension	Style	Description
Perception (LSD - 1)	Sensing	Rather deal with facts, raw data and experiments; they are patient with details, but do not like difficulties.
	Intuitive	Rather deal with principles and theories, are easily bored when presented with details and tend to accept complications.
Input (LSD - 2)	Visual	Easy for them to remember what they see: images, diagrams, timetables, films, etc.
	Verbal	Remember what they have heard, read or said.
Processing (LSD - 3)	Active	Learn by working in groups and handling material.
	Reflective	Learn well when they can think and reflect on the information presented to them. Work better alone or with one more person at most.
Understanding (LSD - 4)	Sequential	Follow a linear reasoning process when solving problems and can work with an explicit material once they have comprehended it partially or superficially.
	Global	Take big intuitive leaps with the information, may have a difficulty when explaining how they got to a particular result, need an integral vision.

The learners' preferences on each dimension may be strong, moderate or mild, and may be modified over time and may differ from one subject or learning environment to another as noted by Ku and Chang (2011).

Felder and Silverman designed the Index of Learning Styles (ILS) which is a 44-question instrument designed to assess LS preferences on the four dimensions of the Felder-Silverman model. Each LS dimension has associated with it 11 questions associated with it which are forced-choice items with each option conforming to one or the other category of the LS dimension. A student's preference for one or the other pole of a given dimension (visual or verbal, active or reflective) may be mild, moderate or strong. The learning style preferences of a student may be affected by a student's educational experience. Felder and Spurlin (2005) suggested that in order to function effectively, students need skills associated with both categories of each learning style dimension.

The most important application of LS, according to Felder and Spurlin (2005), is that it is used to design effective instruction. Knowing the different types of students in a class can assist a teacher to formulate an approach which addresses the needs of all the students (p. 104). Other advantages of Felder and Silverman's ILS are that it can be self-administered, self-scored and self-interpreted. Unfortunately, as Hawk and Shah (2007) assert, there is very little evidence of published research that addresses the validity and reliability of the instrument.

2.2.1 Felder-Silverman learning style model and its relation to other learning style models

The study of different learning style models demonstrates that Felder-Silverman's learning styles model originates from other learning style models such as Jung, Kolb, Dunn and others. For instance, the four bipolar dimensions of the Felder-Silverman model are similar to Jung's type theory. According to Lawrence (1993), the Jung's type theory classified all conscious mental activity into perception, process and judgment processes. This classification is in accordance with Felder and Silverman's (1988) definition of learning styles as a way to take in and process information but, a slight difference exists when details of Jung's type theory and the Felder-Silverman model are examined.

Howard, Carver and Lane (1996) point out that Felder's classification scheme differs from

that of Kolb in that it explicitly acknowledges a visual/verbal learning continuum. Felder and Spurlin (2005) acknowledge that Felder's active/reflective scale is similar to that of Kolb and is based on the extroversion/introversion dichotomy of the Myers-Briggs Type Indicator (MBTI). The sensing-intuitive dimension is very much an MBTI concept and may be similar to Kolb's concrete/abstract dimension. The visual-verbal dimension is unique to the Felder-Silverman model although it bears a resemblance to aspects of visual, auditory and kinesthetic (VAK) approaches. The sequential-global scale is more diffuse in its origin although it is present in the literature in a variety of forms (Schmeck, 1988) and is seen by some as the central axis of learning while the Dunn and Dunn Model is the only one with the sociological dimensions.

There is not a LS element that is found to be common among all the LS models discussed. It has become evident that learning style theorists have attempted to provide a way in which learning can be enhanced through the examination of the various factors that influence learning. In all the learning style models discussed, it was seen that some people have a predominant learning style but this does not mean that they cannot function within other styles although they tend to learn more effectively in accordance to their preferences. It was also seen from the review that a learning style model is just a guideline and not a strict set of rules that must be adhered to.

The Felder and Silverman learning style model was selected as the basic instructional model for the taxonomy of learning and teaching in this study. This is because:

- The model has been developed for improving engineering education in general and hence can be applied to other fields of science, for example, physical sciences.
- Felder-Silverman's learning styles model appears closer to the actual classroom physical science instructional practice.
- The model has been successfully implemented in previous works such as the study by Carver, Howard and Lane (1999), and Hong and Kinshuk (2004).
- The model has been validated by other scholars, for example, Zywno (2003) and Allert (2005).
- It is user friendly and the results are easy to interpret.

- The number of dimensions can be controlled and can actually be implemented (Paredes & Rodriguez, 2002).

Literature based on Felder and Silverman's learning style model is focused on the learning styles profile distribution of engineering students (Harvey, Ling, & Shehab, 2010), but not specifically to physical sciences education in South Africa. Therefore, there are limited studies investigating learners' learning styles and learners' learning-style-based instructions in association with their academic performance in physical sciences.

2.2.2 Felder-Silverman learning styles model and its implications for science education

Palou (2006) states that a good starting point for every teacher to improve the effectiveness of teaching is to understand the different ways students perceive and process information. Thus, in order to understand engineering students' different ways of perceiving and processing information and create a suitable learning environment that matches with learning preferences, Felder and Silverman proposed a four dimensional learning styles model.

Felder and Brent (2005) affirm that there are variables that have implications for teaching and learning processes. These instructional variables fall into three main categories of diversity: learning styles, approaches and intellectual development levels. According to Felder and Silverman (1988), learning involves the information reception and processing steps, that is, students first receive the external information (through the senses) and then process it internally or ignore it. Accordingly, the material (information) may be learned or may not be learned. In this regard, Felder and Silverman's (1988) learning styles model presents details of how different learning style preferences influence the process of learning from information perception to processing.

Regarding the multiplicity of students' learning styles, Felder and Brent (2005) posit that there is a presumption that no learning style is better than the other and that a single instructional approach does not fit with a variety of learning styles. However, one instructional approach may best serve a particular type of learning style, for instance, Felder and Silverman (1988) state that engineering students' drop out, poor performance and disinterest in engineering courses or curricula can be attributed to the mismatch between instruction and learning style strength. Therefore, according to Dubetz, Barreto, Deiros, Kakareka, Brown, and Ewald (2008) in order to reduce students' academic problems and

challenges, information presentation or instruction needs to consider a variety of learning styles.

2.2.3 The influence of Felder-Silverman learning styles on mathematics, science, engineering and technology disciplines

Although understanding students' learning styles may be one step in improving teaching, its relation or match to the nature of subject matter is another important instructional variable to be considered. In the field of science education, several important empirical studies utilising this tool have been undertaken. For instance, Tyndall (2017) determined the effects of adapting instructional methodology when aligned to students' common learning styles on student performance in a health college classroom, using the Felder-Silverman learning styles model as a theoretical framework. Both students' learning styles and corresponding teaching techniques were identified and aligned in the classroom. The findings from the study indicate that students achieved higher grades because of the alignment of teaching and learning styles in the classroom.

A study by James-Gordon and Bal (2001) also shows that engineers at the design department of an automotive company were significantly visual learners. This implies that their instructional environments should be designed in the ways that predominantly match with their visual learning styles.

According to Broberg, Lin, Griggs and Steffen (2008), there is an implicit assumption that engineering technology students and engineering students have similar learning styles. Disregarding differences of learning style distribution across and within engineering disciplines, the overall learning style distribution among technology, engineering and science students was found to be similar (Harvey et al., 2010). However, a comparison between the surveys of the distribution of learning styles of engineering technology students and of engineering students showed a significant variation (Broberg, et al., 2008; Harvey et al., 2010). For instance, the engineering technology students' preference for sensory learning over intuitive learning was significantly higher than for engineering students. Even the data on students' matriculation within survey results showed a notably higher retention of sequential learners for engineering technology students (Broberg et al., 2008). Broberg et al. (2008) further explain that the variations and similarities of learning styles between the engineering technology and the engineering disciplines were attributed to variations in subject

matter and teaching methodology.

A comparative study designed to show learning style distribution of students of science, technology, engineering and mathematics disciplines reveals patterns of similarity and variation. For example, Harvey et al. (2010) and Palou (2006) report that the overall learning style profile patterns of science, technology, engineering and mathematics students were found to be visual, active, sensual and sequential. However, the study also showed significantly different learning style distributions among the disciplines in some learning style dimensions. According to Harvey et al. (2010), a similar pattern of variation was observed among the learning styles of engineering and chemistry students, and within different types of engineering discipline students. For example, under the active/reflective learning styles dimension, civil and industrial engineering students were more active learners than other engineering students, but there were higher numbers of reflective learners in industrial engineering. In the sensing/intuitive dimension, computer science students were found to be intuitive while other engineering students were found to be sensing. In the sequential/global dimension, chemical engineering and computer science students were more global than other engineering students, but there were fewer sequential learners in computer science.

A study was carried out by Akinbobola (2015) on the effects of learning styles and instructional strategies on learners' achievements in Nigerian senior secondary school physics using the learning style model developed by Felder and Silverman (1988). The result showed that guided discovery is the most effective instructional strategy for physics learners with the sensing/intuitive learning style in the concept of electricity. Whereas demonstration is the utmost effectual instructional strategy for physics learners with a sequential/global learning style in the concept of electricity, the conventional strategy is the most effective instructional strategy for learners with the visual/verbal LS. The reason being that, visual learners receive information from visual descriptions such as graphs, diagrams and pictures, while verbal learners favour written or spoken descriptions and formulations, which are characteristics of conventional strategy. This finding parallels the findings of Akinbobola (2011) that audio-visual learners achieved significantly better than learners categorised as kinaesthetic learners when taught using the conventional instructional strategy. It also implies that the three instructional strategies can be used to enhance achievement of learners with different learning styles.

Although, these studies show how learning styles were distributed across and within science, technology, engineering and mathematics students, they did not address the learning styles which helped the students to excel academically in each discipline. For instance, a study by Deonne (2010) reported that learning styles in general and sequential learning styles in particular along with resilience variables enhance academic persistence in engineering programs. However, Deonne (2010) did not mention the other dimensions of learning styles and did not explain why sequential learners were persistent in engineering programs.

2.3 Learning styles critique

According to Reid (2005) and Sparks (2006), there have been criticisms of the concept of learning styles. The criticisms rest on a number of key issues, namely, the lack of credibility and validity of some of the LS tools and the countless opposing perspectives of learning styles (Hulme & Allcock, 2010). According to Kirschner (2017), there is lack of validity, trustworthiness and analytical controls of the LS assessments tools often used by researchers. Stahl (1999) reports discrepancies and low dependability for the measurement of LS when people complete a particular measurement at two different times. That is to say, the test-retest reliability is fairly low. This is often related to the information used to assess LS. The most predominant method is self-reporting. Unfortunately, the suitability of self-reporting for assessing LS is uncertain as argued by Veenman, Prins, and Verheij (2003). This is because most learners are not able enthusiastically or truthfully report what they do or what they think that they do. To demonstrate the unpredictability of self-reporting, Rawson, Stahovich and Mayer (2017) asked students when they did their homework and how long they worked on it. He also gave these students a "smartpen" which noted when and the amount of time they have spent on their homework. The study found that there was a substantial association between the lengths of time students' spent on their homework and their grades as measured by the smartpen; there was no significant correlation between the grade and time spent on homework as reported by the students. That is to say, there was no actual correlation between self-reporting and measurement. Similarly, almost all students remarkably over-reported their homework time.

Coffield et al. (2004) reviewed the 13 most often used instruments for reporting LS with reference to psychometric criteria, namely, internal consistency, test-retest reliability, construct validity and predictive validity. They concluded that three of the models did not

meet any of the four criteria, four met only one criterion, three met two criteria, two met three criteria, and only one met all four criteria. They also posited that these learning style instruments measured cognitive styles and not LSs. Based on Coffield et al.'s (2004) finding, Kirschner and Van Merrienboer (2013) concluded that:

> "When designing instruction that takes differences between learners into account, one should assess cognitive abilities rather than preferred learning styles because abilities are better predictors of how people learn most effectively. Moreover, these cognitive abilities should be objectively measured on an ordinal scale and in an objective way, rather than by subjective self-reports that are used to assign people to types on the basis of one or more arbitrary criteria" (p. 6).

Prashnig (2005), an advocate of LSs and a designer of LS instruments, explains that in one of the most complex and detailed learning style instruments on the market (the Learning Style Analysis (LSA)) there are at least:

> "49 different elements … [with] ... intricate style combinations enhanced by degrees of needs ranging from strong preferences to flexibilities to non-preferences. Given those many style components, it is not possible to label learners by just selecting one style feature as the predominant one" (p. 2).

Kirschner (2017) is of the view that:

> "there is no real scientific basis for the proposition (actually it should be relegated to the realm of beliefs) that (1) a learner actually has a certain optimal learning style, (2) she/he is aware of what that personal learning style is and/or there is a reliable and valid way to determine this style, and (3) optimal learning and instruction entails first determining this learning style and then aligning instruction accordingly" (p. 167)

Kirschner and Van Merrienboer (2013) argued that LS instruments generally classify learners poorly. Most of the instruments categorise learners based on a set of scores on different dimensions, often into exclusive, groups However, as noted in a study by Cuevas (2015), people cannot just simply be clustered into explicit and distinct groups as is revealed in a number of studies (see for example Druckman & Porter, 1991),. Most differences between people are continuing and not nominal. Proponents of using learning styles tend to disregard this and employ random measures such as a median or a mean on a scale to assign a person to specific LS.

According to Coffield et al. (2004), there are 71 models of learning styles and only 13 of these are considered major models. The remaining 58 consist of minor adaptations of one of the leading models and so lack influence. Some models offer new labels for existing constructs as the basis for claiming to be a new model. Others have been used only on very small or homogeneous samples or were briefly popular and then fell into oblivion.

The field of LS research, generally, is far characterised by a very large number of small-scale applications of particular models to small samples of students in specific contexts. Coffield et al. (2004) posit that there have been very few vigorous studies which offer, for example, consistent and valid proof and clear inferences for practice based on empirical findings. Coffield et al. (2004) conclude that "the sheer number of dichotomies in the literature conveys something of the current conceptual confusion" (p. 136).

Another criticism directed at the theory of LS is that there are many opposing views about the term "learning". This has led to an increased propagation of terms and concepts, many of which are used exchange ably in LS research. Examples of such terms are: learning styles, strategies, approaches to learning, cognitive styles, conative styles, cognitive structures, thinking styles, teaching styles, motivational styles, learning orientations and learning conditions. Now and then these terms are used in order to maintain distinctions between theories, at other times they are used very inaccurately and conversely. According to Coffield et al. (2004), some theorists offer clear definitions of their key concepts at the beginning, but forget to sustain the restrictions they have placed on their language in later papers.

Other critiques levelled at the concept of LS highlighting on the impracticality of addressing all the individual LS of all the students in a classroom. There is also much controversy on whether matching individual learning styles to teaching styles and teaching materials does actually produce more effective learning (Bosman, 2015). The commercial element that accompanies a particular learning style perspective also needs to be highlighted. Teachers often have to attend training workshops and purchase expensive materials in order to understand learning styles. As a result, the learning style approach does not always have a sound image in educational psychology literature (Coffield et al., 2004; Reid, 2005).

Sparks (2006) concludes by stating that numerous studies have shown that teaching to a student's learning style does not improve achievements any more than *not* teaching to it (p. 522). Moreover, that a lot of the learning style questionnaires are self-reporting so, if the

students do not understand *how* they learn, they might answer the questions incorrectly.

Critics (for example, Pashler et al., 2009; She, 2005) suggest that the matching of teaching styles with students' learning styles (matching hypothesis) does not help students and should not be implemented in schools. Rinaldi and Gurung (2008) note that a study by Jensen (1987) found that the matching of teaching styles with students' LS did not make a change in student performance. A study conducted by Huxham and Land (2000 cited by Rinaldi & Gurung, 2008) found that students in a class gathered by random selection performed at the same level as students in a class gathered based on LS predilections. Keri (2002) also found that the matching of teaching styles with students' LS did not advance student satisfaction in the learning process. Loo (2004) conducted a study with over 200 undergraduate students and found a weak association between students' LS and partialities for instructional methods.

2.4 Teaching styles

Various researchers and educators suggested that teachers have different teaching styles (Damrongpanit & Reungtragul, 2013; Felder & Silverman, 1988; Kostovich, Poradzisz, Wood, & O'Brien, 2007). Teaching styles are described by Letele, Alexander, and Swanepoel (2013) as the teaching strategies that teachers frequently utilise when teaching. According to Tulbure (2011), most teachers use specific teaching styles which, ultimately, fail students because of their "pervasive uniformity" (p. 398). According to Felder (2010), most college instructors present instructions to accommodate "intuitive skills" (p. 3). The large majority of teachers primarily lecture, but others focus on activities or demonstrations, applications or principles, memorisation or understanding (Felder & Brent, 2005; Kamuche, 2005). However, Felder and Brent (2005) and Felder and Silverman (1988) believe that lecturers in higher education still incorporate teaching styles and strategies which contradict with students' learning styles in lecture rooms, in spite of extensive evidence substantiating the need for considering students' learning strengths

The following five perspectives on teaching, according to More (1996), can help teachers to identify, articulate and justify their teaching approaches: *Transmission* (focus on content, teacher directed); *Developmental* (values, learners' prior knowledge, learners to develop more complex understandings); *Apprenticeship* (authentic tasks in real world settings); *Nurturing* (focus on interpersonal elements and learners' emotional and intellectual needs); and *Social*

reform (relate ideas explicitly to the lives of the learners).

2.4.1 Felder-Silverman's interpretation of teaching styles

Felder and Silverman (1988) defined teaching style in terms of the answers to the following five questions (p.675):

(1) What type of information is emphasised by the instructor: concrete – factual, or *abstract – conceptual*, theoretical?

(2) What mode of presentation is stressed: visual – pictures, diagrams, films, demonstrations, or *verbal* – lectures, readings, and discussions?

(3) How is the presentation organised: inductively – phenomena leading to principles, or *deductively* – principles leading to phenomena?

(4) What mode of student participation is facilitated by the presentation: active – students talk, move, and reflect, or passive – students watch and listen?

(5) What type of perspective is provided on the information presented: sequential – step-by-step progression (the tree), or global – context and relevance (the forest)?

According to Felder et al. (2002), in the interpretation of teaching styles, teachers may emphasise concrete information (facts, data and observable phenomena) or abstract concepts (principles, theories and mathematical models) during the dissemination of information. In addition, when a teacher focuses on presentation, she/he may either stress the visual representation of information (chalkboard illustrations, pictures, diagrams, sketches, process flow charts, network diagrams, graphs) or the verbal (the information presented by the teacher is predominantly auditory or involving the use of words). Therefore, the organisation of lessons could either be inductive (the teacher precedes presentations of theoretical material that the theory will explain, infers the governing rules or principles that explain the observed phenomena and deduces other implications and consequences of the inferred principles) or deductive (where the generalised rule is mentioned and this leads to observed examples).

Teachers could prefer learners' participation that is active (discussion, brainstorming or problem-solving activities) or passive (observing and listening to the teacher).

Lastly, teachers may prefer a sequential mode of presenting information (step-wise presentation of information) or global by providing the big picture or goal of a lesson before presenting the steps, doing as much as possible to establish the context and relevance of the subject matter and relating it to the students' experiences.

Surprisingly, these guidelines do not apply to most science classrooms across South African high schools. Science teachers preparing grade 12 learners for matric examination mostly focus on completing the syllabus instead of differentiating instructions for learner understanding. As such, the dominant instructional technique often used by science teachers across Mthatha is the lecture method, where learners become passive participants in the teaching/learning process and teachers are at the centre of instruction.

2.4.2 Anthony Grasha's interpretation of teaching styles

According to Grasha (1996), a teaching style is viewed as a particular pattern of needs, beliefs and behaviours that teachers display in the classroom. His study shows several patterns describing the stylistic qualities of teachers. These qualities describe the teacher as:

- *Expert* (transmitter of information): Within this style, the teacher possesses the knowledge and expertise that the learners require. The learners are required to be prepared to learn and use the information from the teacher.

- *Formal Authority* (sets standards and defines acceptable ways of doing things): The teacher provides learners with materials that are necessary for them to learn. While this model may focus on clear expectations, it can become too rigid in terms of managing learners and their concerns.

- *Personal Model* (teaches by illustration with direct examples): The teacher becomes the prototype for how to think and behave. He/she encourages learners to observe and emulate his/her approach.

- *Facilitator* (guides and directs by asking questions, exploring options, suggesting alternatives): This style focuses on learner needs and goals and allows for creative thinking. However, the style is seen as time consuming.

- *Delegator* (develops learners' ability to function autonomously): The focus is to allow

learners to work independently or in autonomous teams with the teacher. This style helps learners to see themselves as independent and in charge of their learning (Grasha, 1996, p. 154).

Grasha (1996) believes that every teacher possesses each of the five teaching styles to varying degrees. In effect, each teacher's style can be compared to "different colours on an artist's palette", which can be blended together. Grasha later showed in his studies that the teaching styles previously identified form four blends or clusters of teaching styles as shown below.

- Cluster 1: Expert/Formal Authority
- Cluster 2: Personal Model/Expert/Formal Authority
- Cluster 3: Facilitator/Personal Model/Expert
- Cluster 4: Delegator/Facilitator/Expert

Grasha (1996) indicated that each cluster of teaching style helps to create the mood of a class. Traditionally, the styles displayed in Clusters 1 and 2 are teacher-centred. In contrast, an emphasis on the Delegator/Facilitator/Expert blend of Clusters 3 and 4 creates an environment for teachers and learners to work together (learner-centred). Grasha (1996) suggests that teachers can still explore alternative teaching styles and classroom processes based on the specific goals they want to achieve. He also points out that teachers are free to shift their styles of teaching from one cluster or can integrate several aspects of the instructional processes in Clusters 2, 3, or 4 in order to achieve their goals.

2.4.3 Pratt's interpretation of teaching styles

Pratt (2002) designed an instrument named "Teaching Perspectives Inventory" (TPI) which examines numerous constituent of the teaching processes. These constituents namely; teachers, students, the subject content, the context and standards were used as a basis to identified five unique perspectives on teaching. These perspectives are:

- *Transmission*: Authentic teaching starts with a considerable focus on the delivery of content. The teacher focuses on content and defines what and how learners should learn.

- *Developmental*: The teacher capitalises on learners' previous knowledge and uses

effective questions and meaningful examples to challenge learners to move from simple to complex forms of reasoning.

- *Apprenticeship*: Learners work on activities that are significant, appropriate and related to real life situations.

- *Nurturing*: The teacher focuses on the interpersonal features of the learners' learning. This includes motivating, encouraging and supporting learners by listening to and getting to know them and responding to their emotional and intellectual needs.

- *Social reform*: The teacher relays ideas clearly to the lives of the learners by bridging prior knowledge and concepts, and respecting and promoting the dignity of every learner.

When teaching takes place in or out of the classroom, learners are expected to learn (Pratt, 2002) and therefore, teachers can benefit from understanding and applying certain principles of learning when designing and implementing their teaching styles.

2.5 Matching learning styles and teaching styles

Learning and teaching styles are major factors connected with student success or failure in school (Damrongpanit & Reungtragul, 2013). According to Felder and Silverman (1988), the matching of teaching styles with students' learning styles is needed for improved student performance in higher education. Studies by Bernardes and Hanna (2009) and Mangino and Griggs (2007) suggest that matching learning styles with teaching styles can result in students' higher achievement. Fritz (2002), Gauss (2002) and Williamson and Watson (2007) believe that, if lecturers know their students' learning styles, they can match their styles of teaching to the learners' Ls, thus making their instructions more effective. For example, a study by Dunn, Deckinger, Withers and Katzenstein (1990) established that teaching through learners' learning styles enhanced students' achievements. This was also confirmed by Bowles (2004) who attests that educational processes informed by learning styles are more effective. However, Williamson and Watson (2007) caution that the matching of learning styles and teaching styles over a long period of time could make both teachers and learners too comfortable and render the learning environment less challenging. The researcher concurs with this viewpoint and argues that, if teachers continuously matched learning styles to

teachers' instructional strategies, learners will not be able to engage in constructive debate and critical thinking, making learners reluctant to learn.

Intentional mismatch should therefore be encouraged (Williamson & Watson, 2007) so that both the students and the lecturers can develop and explore alternative learning styles thus adjusting to different learning environments. It is important, therefore, for teachers to help learners to understand the limitations of their preferred learning styles and assist them to expand their learning styles so as to succeed in a variety of learning environments.

Matching teaching styles with students' learning styles does not mean that the teacher should adjust the teaching style to every individual student's learning style, nor that the teacher should use an all-encompassing teaching style for all students. Rather, a more balanced teaching strategy, one that accommodates the different learning styles in the class, is appropriate (Felder & Brent, 2005). Felder and Brent (2005) assert that a teaching style that responds to one learning style would not address the needs of the rest of the students in the class. Kolb (1984) and Robotham (1999) argue that learners come to a learning environment with a learning style already developed and that, if they find a mismatch between their own learning styles and the teachers' teaching styles, they may reject the learning environment. Mismatch between teaching styles and learning styles could make students lose interest in class, leading to poor performance on tests and examinations, to failure of their courses, and ultimately to dropping out (Felder & Silverman, 1988; Williamson & Watson, 2007).

In spite of the availability of a large volume of evidence to substantiate the need for aligning teaching and learning styles, program designers in the field of education are still somewhat reluctant to incorporate it in schools (Abidin, Rezaee, Abdullah, & Singh, 2011; Letele et al., 2013; Ültanir, Ültanir, & Temel, 2012). Therefore, learning and teaching styles are key factors to consider in developing a more learning-friendly environment for both students and teachers (Coldren & Hively, 2009; Tucker, 2011).

Proponents of the learning styles framework (for example, Aliweh, 2011; Felder & Silverman, 1988; Kyprianidou et al., 2012; Tulbure, 2012) believe that congruence between teaching and learning styles is an effective pedagogical approach designed by best practice. Lopus and Hoff (2009) note that congruence between teachings and learning styles is essential because students are underperforming in high schools and colleges due to the incongruity of teaching and learning styles in classrooms. Various researchers (for example,

Brahmakasikara, 2013; Felder & Silverman, 1988; Ku & Shen, 2009; Tsai, 2013) conclude that teaching strategies should be adjusted to improve students' chances for succeeding in schools. Damrongpanit and Reungtragul (2013) also indicate that there was a close connection between student success in school, learning styles, characteristics and skills.

A study by Cassidy (2004) found that the way in which students are predisposed to encounter information in school greatly affects their academic achievement. Other research studies, for example, Abidin et al. (2011) and Orr, Park, Thompson and Thompson (1999), also indicate that students perform better in school when attention is placed on their learning styles rather than on the material covered. Pass, Mehta and Mehta (2012) examined research results which found that the matching of instructors' teaching methods with students' preferred methods for learning directly influenced student performance. Research by Packer and Bain (1978) suggests that it is easier for students to appreciate the learning process when teachers' teaching styles are in alignment with their learning styles. The examination of research findings from 19 studies by Kostovich et al. (2007) established that the alignment of teaching methods with students' LS improved student performance. Another study by Kamuche (2005) conducted with 3,000 students from 2002 to 2005 at the Morehouse College found that students' test scores substantially increased when their learning styles were matched with teachers' teaching styles

2.6 The current trends in teaching/learning style theories

The review of related studies has shown that learners have different LS and that effective instruction requires identifying the LS of each learner and aligning instructions according to their LS preferences. It is also evident from the analysis of the five LS models presented above (Dunn & Dunn, 1992; Felder & Silverman, 1988; Gregorc, 1979; Kolb, 1984; Lawrence, 1993) that their authors believe that using LS tools could be used to enlighten the selection of learning activities and instructional methods would improve the value and worthy of education for learners as evident in the studies by Hawk and Shah (2007).

There are, however, criticisms levelled against the use of learning/teaching styles in education. Kirschner and Merriënboer (2013) argue that many people do not fit one particular learning style and the information used to assign people to their learning style preferences is often inadequate. They state that there are so many different learning/teaching styles that it

becomes cumbersome to link particular learners' learning styles to a specific teaching style. Furthermore, some researchers (Veenman et al., 2003) contest the information used to determine learners' learning styles. Their argument is that, since self-report measures are used for the assessment of learning styles, their adequacy is questionable. Stahl (1999) also reports low reliabilities for the measurement of learning style instruments. He argues that, when individuals complete a particular measurement at two different points in time, the results are very often inconsistent.

A contradictory argument that these critics of learning styles have ignored is the effect of culture and Indigenous Knowledge Systems (IKS) on learning styles. Ramirez and Castaneda (1974) believe that learning styles are created by cultural differences as well as by the individual tendency to prefer a particular learning style. In contrast, several well-designed recent studies (e.g., Akinbobola, 2015; Magulod, 2019) show that learners have different learning styles and the responsibility of the teacher is to identify these learning style differences and employ appropriate instructional strategies to align with preferred styles to enhance effective teaching and learning. This view contradicts the views put forward by Kirschner and Merriënboer (2013), Stahl (1999) and Veenman et al. (2003).

These contradicting findings from the literature highlight the need for further research, particularly into whether there are correlations between learning style-based instructional strategies and learner achievements and also if there are benefits for using learning style-based instructional strategies in the physical science classroom by taking the learners' cultural backgrounds into consideration. Regardless of the evident benefits of differentiated instructions, they may not be the most efficient technique for enhancing learning. Although Abidin et al. (2011) and Walton (2010) perceive links among learning style preferences and academic achievements of learners, these studies did not explicitly address issues on learning style-based instructional methods of teaching. Akinbobola's (2015) study might have been another attempt, but since he only explored the interplay between differentiated instructions (guided discovery, demonstration and conventional instructions), learning styles and academic performance among learners, he ignored the aspect of cultural attributes that may impact learning style preferences.

Therefore, this study was particularly necessary to fill the gap in the literature by exploring learners' academic achievements in physical sciences through learning styles and learning

style based instructional materials in Mthatha high schools to clarify the relationships among learning style preferences and the cultural background of learners.

2.7 The impact of culture on learning style preferences

Hofstede (2001) defines culture as "the collective programming of the mind that categorises one group of people from another. Accordingly, House, Hanges, Javidan, Dorfman and Gupta (2004) define culture as shared motives, beliefs, identities, values, and interpretations of important events that result from common experiences of members that are transmitted across generations. From these definitions, the researcher argues that culture is the way a group of people live that includes the food they eat, the way they dress, the language they speak and the values they hold and that this may influence the way they process information in a learning environment.

2.7.1 Characterising cultural differences

Hofstede (2001) highlighted on the cultural dimensions as the basis for characterising culture. Cultural dimensions are various categories into which attributes of the cultures are classified. Hofstede (2001) identified the primary attributes on which cultures differ in the following cultural dimensions:

- individualism-collectivism;
- uncertainty avoidance;
- power distance;
- masculinity-femininity; and
- Long-short term orientations.

However, the researcher argues that all the above dimensions have implications for learning style preferences.

2.7.2 The relationship between cultural attributes and learning style preferences

Hofstede's (2001) study reveals that differences in childhood socialisation between individual and collective communities lead to differences in personal and behaviour patterns among family members. Learners who grow up in collective communities learn to reason

instinctively as part of belongingness. Moreover, coordination in the group is cheered, stressing on group norms and standards. Of paramount is the fact that the learning processes lies in the way information is synthesised and processed. In collective communities, instinctive empathetic of a situation plays a vital role. Absolute allegiance is anticipated and assumed in collective cultures, whereas individual excellence is nurtured and renowned in individual cultures. This attribute is also characteristic of Sensory-Intuitive learning (or Perception) of the FSLS model.

Uncertainty avoidance refers to the way risks are viewed and avoided. For example, in communities with a high degree of uncertainty tolerance, rules may be specified more loosely and infractions viewed more leniently (Manikutty et al., 2007). In communities with a low tolerance for ambiguity, rigid rules and procedures tend to be specified to ensure a high predictability of behaviour. In such communities, learners try to gather as much information on a topic as possible, will refer to other sources of information and will prefer to reason out things by themselves. This attribute is also a characteristic of the Active/Reflective LS preference (or Processing) of the FSLS model.

Power-distance is the degree to which the community consents and expects an unequal distribution of power. In this context, it means the relationship between teachers and learners. Hofstede (1986) argues that power-distance plays a significant role in determining learner/teacher relationships. The teacher is ranked higher regarding the knowledge and authority vested in him/her. Therefore, the teacher's wisdom and teachings are taken as authentic and are not questioned. Thus, class discussions tend to be more like clarifications rather than actual debates on what the teacher has taught. Learners look up to their teachers in everything they teach. This is a characteristic of visual/verbal (or input) of the FSLS model.

Hofstede distinction between masculine and feminine cultures does not relate to gender issues but to assertiveness, competitiveness and higher ambition which characterise a masculine society. Masculine societies tend to place great importance on tangible success. In a learning situation in masculine cultures, teachers openly praise good learners, set best learners as the benchmark, reward good performance and create an intense, though stressful climate.

Hofstede's (2001) distinction between long and short-term orientation relates to the degree to which a culture drives its members to accept delayed gratification of their material, social and emotional needs. In cultures with a long-term orientation, results are not seen as "here and

now" and whilst waiting to achieve something in the longer term, which has been encouraged and cheered. Long-term attribute of culture also reflects a firm belief in tradition. In societies with a short tern orientation, emphasis is placed on practice and good behaviour as specified by the tradition in that culture. Therefore, education in societies with long time orientation is viewed as a gathering of information that is needed to acquire the skills that are necessary for the long-term goal of finding a well-paid job.

In this study, the masculine/feminine attribute of culture was not considered since it appears to be more focused on gender. Table 2.3 shows the interconnection between the Felder-Silverman (1988) learning style preferences and Hofstede's (2001) cultural dimensions.

Table 2.3: The relationship between Hofstede cultural attributes and FSLS preferences

Cultural attribute	Description	Learning Styles
Individualism-collectivism	In family relations, they value honesty/truth, talking things out, using guilt to achieve behavioural goals, and maintaining self-respect.	Perception
Power distance	This dimension reflects the consequences of power inequality and authority relations in society.	Processing
Uncertainty avoidance	This aspect deals with the need for well-defined rules for prescribed behaviour. People seem active, emotional, and expect structure in organisations, institutions, and to help make events clearly interpretable and predictable.	Input
Long-term orientation	Long-term orientation "stands for the fostering of virtues oriented towards future rewards, in particular, perseverance and thrift.	Understanding

Anderson (1988) believes that the components of a culture are built upon a fundamental conceptual system or common world-view. This conceptual system has patterns of beliefs and values that define the manner in which people judge, act, decide and solve problems, and therefore differs from culture to culture. Matthews (1973 cited in Anderson, 1988) explains that the conceptual system is transmitted to its members through socialisation practices where the member learns patterns of behaviour through role modelling and imitating.

Widespread studies (for example, More, 1990; Tripp, 2011) reveal a strong link between culture and LS preferences. Research (for example, More, 1996) suggests that ways of learning and the LS one prefers are fundamentally learned from relatives, close family and

friends. It is here that the child learns content and skills as well as how to learn (Berry, 1976). Numerous research have been carried out to determine the effects of culture on learning and report a strong correlation between the learning styles of people within particular cultures (Dunn et al., 1989; More, 1987). More (1987), in comparing cultural/cognitive styles, notes clear differences amongst people of different cultures. Messick (1975) also found that ethnic groups show distinctive forms of thinking styles that are amazingly different from one another.

Guild (1994) notes that certain "cultures do have distinctive learning style patterns, but the great variation among individuals within groups means that teachers must use diverse teaching strategies with all learners" (p. 16). This means that knowing the learning style of each learner, especially his or her culture, is fundamental preparation for facilitating, structuring, and authenticating successful learning for all learners. Hickson, Land and Aikman (1994) are of the opinion that, although education is regarded as a right of all children, teachers have not apprehended the degree to which ethnic and cultural differences influence learning and achievement.

More (1987) further emphasises the need for teachers to realise the importance of cultural upbringing in the learning context. More (1990) and Guild (1994) argue that overlooking the influence of culture on learning styles impede learning and contribute to underperformance and high drop-out rates in among learners in schools. Bennett (1986) warns teachers that "if classroom expectations are limited by our own cultural orientations, we impede successful learners guided by another cultural orientation" (p.18). Boyer (1983) notes the significance of modifying the belief systems of teachers that have embraced academic discrimination through in-service training programmes that address different understandings about the way in which individuals from diverse cultures communicate, behave and learn. Many writers in the field of LS and culture (for example, Guild, 1994; More, 1987; 1997) conclude that since ways of learning and LS are learned from the people who are important to us, as well as from our life experiences, culture must have a significant influence on LS.

2.8 Theoretical framework of the study

Borgatti and Foster (2003) define "theoretical framework" as a collection of related concepts which guide the research, determining what things the researcher will investigate and how

she/he will analyse and interpret data. In addition, Merriam (2001) describes the theoretical framework as "the structure, the scaffolding, and the frame of the research study" (p. 45). This structure comes from the researcher's study orientation, the literature reviewed on the topic and the theoretical foundation for the study. From these sources, a case is built for the significance of the study through an analysis of the concepts, models and theories found in a literature base and seen through a particular disciplinary orientation. By drawing from the findings of the literature reviewed, this study was informed by theoretical frameworks that consider circumstances under which people deal with information-processing that have implications for both teaching and learning. The definition of learning style-based instructions in this study therefore, straddles three key theoretical positions, Approaches to Learning Style Models, Constructivism, and Brain-Based Learning Theory. These three, together with the link between LS and cultural border crossing theory formed the theoretical framework of this study.

Constructivism, Approaches to Learning style Models and Brain-Based Educational Theory have relevance to the study of LS preferences and instructional strategies in relation to learner achievement. Below, each of the three theoretical lenses is explicated.

2.8.1 Approaches to learning style models as a pedagogy for science

Felder and Silverman (1988) define learning style as the characteristics, strengths and preferences in the way people receive and process information. This indicates that every individual has its own method or set of strategies when learning. According to Sewall (1986), there are several theories/models about learning styles. For this study, Felder-Silverman's model was selected as the pedagogical basis for teaching and learning as this model has been successfully implemented in previous works.

Considering that pedagogy includes teaching and learning strategies, the researcher provide a definition of both. Learning strategies are the approaches used to remember, learn and use information. In this case, the responsibility relies on the learner. Learners go through a process where they recognise the new knowledge, review previous concepts, organise and restore that previous knowledge, match it with the new one, assimilate it and interpret everything that was seen on the subject. The Felder-Silverman learning styles model recognises that there are multiple dimensions of learning. The dimensions form continua such

that everyone can place themselves along a line from one pole to its opposite. This allows for almost infinite variations in the configurations. This configuration constitutes a learning style profile. Correspondingly, there are dimensions of teaching style.

Teaching strategies are the elements given to the learners by the teachers to facilitate a deeper understanding of the information. The emphasis is on the design, programming, elaboration and accomplishment of the learning content. Teaching strategies must be designed in a way that learners are encouraged to observe, analyse, express an opinion, create a hypothesis, look for a solution and discover knowledge by themselves.

Felder and Silverman (1988) implemented many teaching approaches to match the learners' learning style preferences. In the midst of diverse elements of teaching strategy, Dunn (1990) insists on the importance of teaching the learners by using methods that adapt to their conceptual preferences. Cabrero (2006) also contends that implementing diverse teaching strategies will impact on the quality of teaching from a collaborative point of view.

One crucial aspect of this research was the integration of learning styles with teaching strategies while, on the other hand, there was the need to link such teaching strategies with the concept of learners cultural backgrounds, something that has not been exploited to the extent that was intended here.

2.8.2 Constructivism as a framework for deciding instructions

According to Hoover (1996, as cited in Bada & Olusegun, 2015), constructivism has its roots in philosophy, psychology, sociology and education. Although it is important for teachers to understand constructivism, it is equally important to understand the implication this view of learning has for teaching and the professional development of the teacher as suggested by Tam (2000). According to Bada and Olusegun, (2015), "constructivism's central idea is that human learning is constructed so that learners could comprehend new information upon the basis of prior learning (p.67). This acquisition of new knowledge of learning abruptly differs from the one in which learning is the unreceptive passage of material from one person to another, a view in which responded, not structure, is vital (Hoover, 1996; Bada & Olusengun, 2015). According to Hoover (1996), in constructed knowledge, students create new understandings using what they already know and previous experiences influence what new knowledge they will construct from new learning experiences.

Hoover (1996) opined that constructivism has two central ideas. The first idea is that learners construct their own knowledge employing their prior experience and that prior experience alters information they will create from their new learning environment.

The second idea centres on the fact that knowledge is acquired actively and that learners challenge their thought in light of what they come across in the new learning environment. If what learners come across is inconsistent with their present understanding, their understanding can change to accommodate the new information. Learners continue to be active throughout this process: they apply current understandings, note appropriate features in new learning experiences, judge the consistency of prior and emerging knowledge and, based on that judgment; they can adjust their understanding (Phillips, 1995). Bada and Olusengun (2015) opined that, in the constructivist classroom, the attention inclines to shift solely from the teacher to the students. The classroom is no longer a place where the teacher transfers information unto unreceptive students who wait upon the teacher like empty barrels to be filled. The teacher functions more as a facilitator who mentors, trains, mediates, prompts and helps students develop and evaluate their empathetic and learning in the new environment.

In this study, the social constructivist framework guided both the methodology and data analysis as the framework assisted in the design of instructions by checking whether learner involvement in science processes moved them from passive learners to active learners.

Fosnot and Perry (1996) argue that constructivism has implications for science teaching and learning in that:

- learning is not the consequence of development; learning is development. It requires invention and self-organisation on the part of the learner. Therefore, teachers need to allow learners to raise their own questions, generate their own hypotheses and discuss them.

- disequilibrium facilitates learning. “Errors” need to be perceived to be a result of learners’ conceptions, and are therefore not to be avoided.

- reflective abstraction is the driving force of learning. As meaning makers, humans seek to organise and generalise across experiences in a representational form.

- dialogue within a community engenders further thinking. The classroom needs to be

seen as a “community of discourse engaged in activity, reflection, and conversation”.

2.8.3 Brain-Based Learning Theory in the design of learning experiences

According to McCarthy (2000), there are various viewpoints regarding how learners perceive and process information. The Brain-Based theories primarily focus on the brain’s function in the learning process. The brain plays a pivotal role in the learning process which primarily deals with one’s tendency for receiving, processing, and expressing information (Connell, 2009; Wilson, 2012). Hebb (1949) suggests that the left and right hemispheres of the brain employ different strategies while receiving information in different ways. According to Jensen (2008), each hemisphere contributes its special functions to cognitive, affective and physical activities and is nerve cell rich. Sprenger (2002) notes that the hemispheres spontaneously determine the time spent on thinking about a particular issue (and the brain serves its function as a whole).

Several educators and brain researchers, including Felder (1996), have conducted research and produced materials related to learners’ learning styles in comparison to the brain’s hemispheres. Thus, Brain-Based Learning Theory is a way of thinking about the learning process. Jensen (2008) believes that the Brain-Based Theory is a set of ideologies and a foundation of knowledge acquisition and skills through which we can make better judgements about the learning process. In addition, Caine, Caine and Crowell (1994) are of the view that Brain Based Learning theory involves understanding the functions of the brain, and then incorporating this in designing learning experiences, which they affirm can significantly improve the effectiveness of learners’ learning. Thus, the theory takes into consideration the natural and physiological processes that occur during learning and uses this understanding to guide educational practice. Kolb (1984) opined that the adaption of instructional methodology to align with learners’ left or right-mode predispositions is capable of improving learner performance in school

The brain and its networks, according to Ültanir et al. (2012), originate at birth and lead to the differences in perceptions, which eventually develop into variations in learning tendencies. In addition, genetics is responsible for “three-fifths of a person’s learning” (Abidin et al., 2011, p. 143). The right and left brain hemispheres operate both separately and collectively for the incorporation of information encountered, and right or left mode preferences of the brain

determine the manner in which people receive instructions and process information (Duman, 2010; Springer & Deutsch, 1989). Kolb and Kolb (2005) were of the view that meaningful learning ensues in a harmony of transmission of information because the brain works in unison while learning. Therefore, based on the findings of neuroscience, Brain-Based Learning is guided according to the principles and workings of the brain to find the best way of learning, increase academic achievement and provide equal opportunities for individual differences.

2.8.4 The link between learning style-based instructions and cultural border crossing

The multifaceted aspects of culture differentiate various social groups within a community, including the learners' home culture, from the school's culture (Piliouras & Evangelou, 2012). Some educational researchers (e.g., Hanrahan, 2002) posit that, learners from diverse cultural backgrounds often experience difficulty navigating within schooling institutions. In this context, a learner's transition into school science may be an unfamiliar and confusing procedure. This transition can be seen in terms of "border crossing", a term first used by Giroux (1992). Aikenhead (1996) applied the work of Giroux to school science by suggesting that, when learners learn science, they often cross a cultural boundary from their own home culture into the subculture of a science classroom. Aikenhead (1996) conceptualised this transition between the learners' home experiences and school science experiences as a "cultural" border crossing.

Giroux (1997) proposed a border pedagogy which, as pedagogical practice, underscores the need to challenge and resist existing boundaries of knowledge and create new ones. In the context of border pedagogy, it is imperative to create classroom conditions that facilitate the learners' ability to speak, write and listen in a "multi-perspectival language" (p. 30). In the context of border pedagogy, "teachers become border-crossers when they legitimise excluded social narratives, experiences and voices and make them available in the classroom" (Giroux, 1997, p. 30).

For an effective, culturally sensitive and inclusive instruction, teachers need to understand the way cultural border crossings take place. Learners' achievements in science largely depend on the assistance they receive when they attempt to cross these cultural borders. In this regard, Jegede and Aikenhead (1999) suggest that success in science courses depends on:

- the degree of cultural differences that learners perceive between their home and their science classroom;
- how effectively learners move between their home culture and the culture of school science; and
- the assistance and the support learners receive in making those transitions easier.

Jegede and Aikenhead (1999) also propose a special culture-sensitive pedagogy for cross-cultural science teaching in which teachers play the roles of cultural brokers in the classroom in order to achieve a culturally sensitive curriculum and assessment.

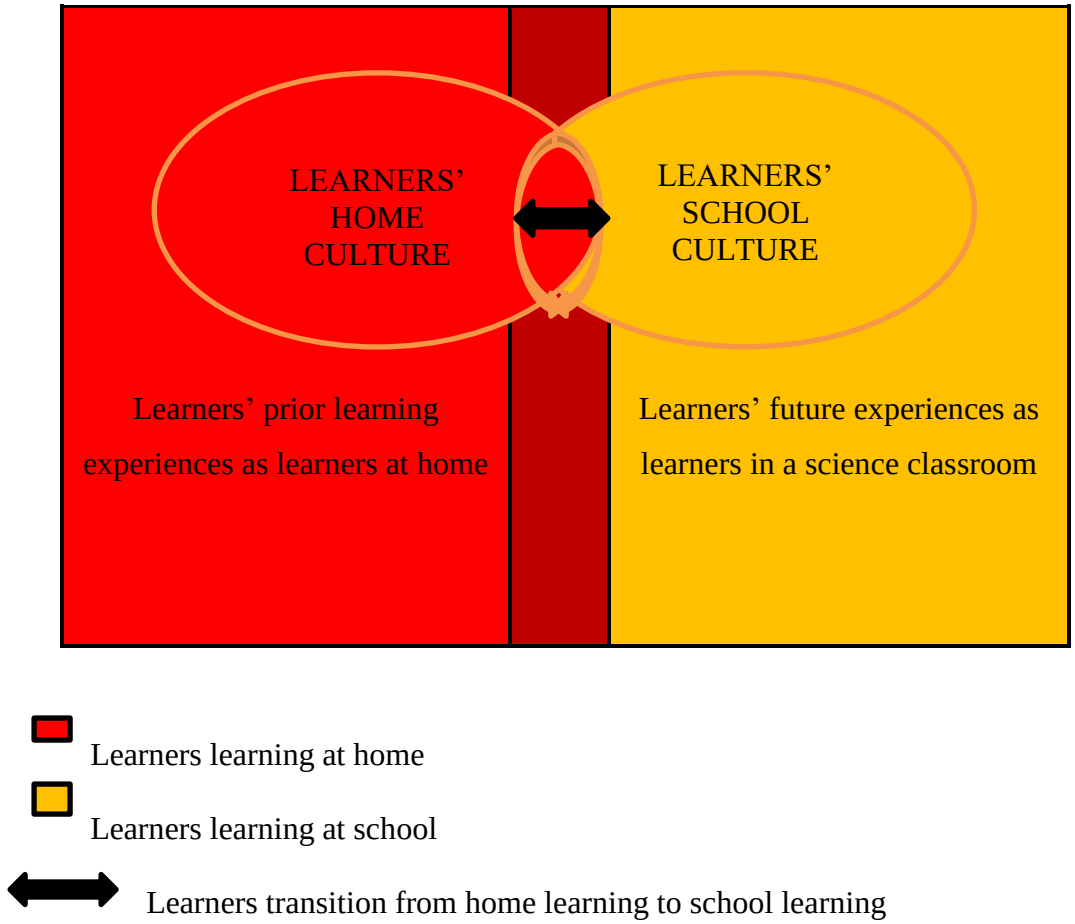


Figure 2.4: The transition of learners from home culture to school culture
Source: Adapted from Kang, Bae and Chang (2012).

In this study, a border crossing framework guided the participating science teachers to assess and adapt instructions to learners' abilities and understanding, considering their cultural backgrounds. As Ball (2000) argues, most teachers find it difficult to bridge knowledge of

subject matter with pedagogy to make use of learning style-based instructions in ways that help learners to cross the border from home learning to school science learning.

The implications of border crossing to science teaching and learning

The implication is that teachers must assess and adapt instruction to learners' abilities and understanding (Kang et al., 2012). Crossing borders have also been suggested to promote learning as part of traditional activity theory described by Engeström (1987). Teachers should give attention to the language of science and help pupils who are accustomed to an oral tradition or who have language difficulties. Snively (1995) delineates specific instructional strategies and considerations for teachers to use when teaching science (p. 16). These are summarised below:

- show learners how concepts such as heat, snow and life cycles are culture-laden.
- provide sensory experiences and experiential pupil-centred learning instructions.
- provide a "multicultural view" of science and technology by drawing upon a variety of cultures when teaching science.
- Interactivity among pupils should encourage them to identify their own ideas and beliefs.

2.9 Conceptual framework

In section 2.8, a theoretical framework was explicated as the theory that a researcher chooses to guide him/her in his/her research. Thus, "a theoretical framework is the application of a theory, or a set of concepts drawn from one and the same theory, to offer an explanation of an event, or shed some light on a particular phenomenon or research problem" (Imenda, 2014, p.189).

On the other hand, a researcher may opine that his/her research problem cannot meaningfully be researched in reference to only one theory, or concepts resident within one theory. In such cases, the researcher may have to "synthesize" the existing views in the literature concerning a given situation – both theoretical and from empirical findings. The synthesis may be called a *conceptual framework*, which essentially represents an 'integrated' way of looking at the problem (Liehr & Smith 1999). Such a model could then be used in place of a theoretical framework. Thus, "a conceptual framework may be defined as an end result of bringing

together a number of related concepts to explain or predict a given event, or give a broader understanding of the phenomenon of interest – or simply, of a research problem" (Imenda, 2014, p.189). The process of arriving at a conceptual framework is akin to an inductive process whereby small individual pieces (in this case, concepts) are joined together to tell a bigger map of possible relationships. Thus, a conceptual framework is derived from concepts, in-so-far as a theoretical framework is derived from a theory.

Hence, a conceptual framework embodies the researcher's synthesis of literature on how to explain a particular phenomenon. It maps out the actions required in the course of the research given the researcher's knowledge on the review of the literature. In other words, the conceptual framework is the researcher's understanding of how the variables in the study connect with each other. Thus, it is the researcher's "map" in pursuing the study. As McGaghie, Bordage, and Shea (2001) put it: the conceptual framework "sets the stage" for the presentation of the specific research question that drives the investigation being reported based on the problem statement (p. 923). The problem statement presents the context and the issues that caused the researcher to conduct the study. Therefore, the conceptual framework lies within a much broader framework called theoretical framework. The latter draws support from time-tested theories that embody the findings of many researchers on why and how a particular phenomenon occurs.

Conceptual framework therefore, identifies the research variables and clarifies relationships among the variables, and hence, link to the problem statement. According to Varpio, Paradis, Uijtdehaage, and Young (2019), a conceptual framework: (1) describes the state of known knowledge, usually through a literature review; (2) identifies gaps in our understanding of a phenomenon or problem; and (3) outlines the methodological underpinnings of the research project. Accordingly, the conceptual framework of the most important variables operating in this study is mapped in Figure 2.5 and they are detailed in the section that follows. The major terms explored and operationally defined are: learning, learning styles, teacher instructional practices and learner achievements in physical sciences.

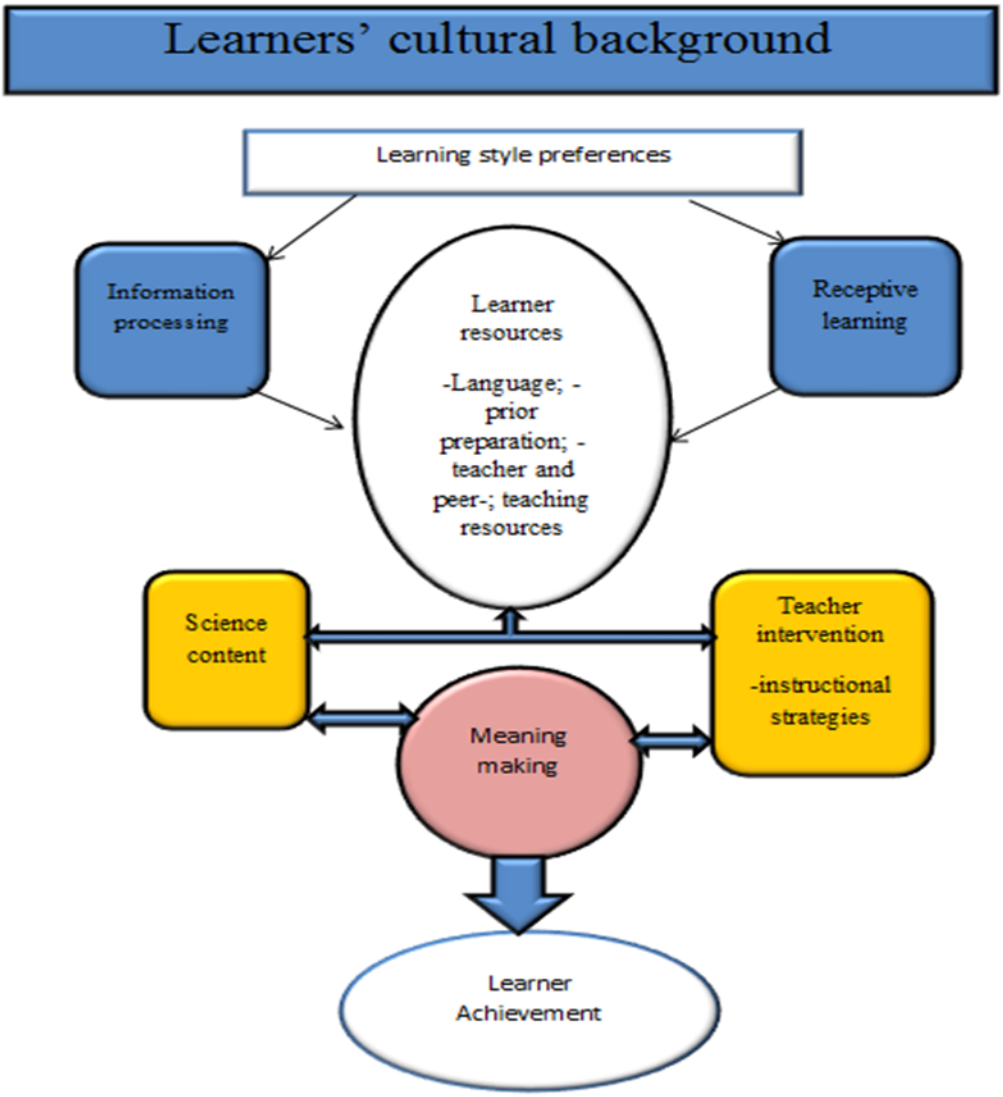


Figure 2.5: Interactions between major concepts forming the conceptual framework for the current study

Learning

Learning can be defined from a number of perspectives: the experiential or phenomenological perspective, the behavioural perspective and the neurological perspective (Schmeck, 1998). When referring to learning styles and learning approaches, the primary perspective used is a phenomenological perspective. The focus of the phenomenological approach is to "step back from ordinary assumptions regarding things and to describe the phenomena of experience as they appear rather than to attempt to explain why they appear that way" (Marton 2004, p.1). Booth (1992) opined that "learning is always learning something" (p.53).

For both learning styles and learning approaches, learning from a behavioural perspective is

also important as it is only through observable change that we can see if learning has occurred. As Ramsden (1992, p.4) notes "learning in educational institutions should be about changing the ways learners understand, or experience, or conceptualise the world around them." However, it is important to note that an individual's learning style or approach cannot be inferred from the individual's behaviour. This is discussed in more detail below, under learning styles. Learning considered from a neurological perspective, and the way facts can be effectively stored and retrieved if they are embedded within the overall framework of the individual, is important when considering deep and surface learning approaches.

Learning styles

The concept of learning styles was introduced in the 1960s. It was based on the principle that all individuals are capable of learning, but varies enormously in the speed and manner in which they pick up new information and ideas, and the confidence with which they process and use them. This all translates into learners having their own styles of learning or 'learning fingerprints' which create a landscape by which they will either maintain or restrain their own learning (Coffield, et al.,2004; Daghani & Akkoyunlu 2012; Gappi 2013; Reid 2005). However, learners can and should develop their abilities to use those learning styles which are not their natural modes and preferences (Hawk & Shah 2007). Nevertheless, learning styles is not a univocal concept. Regardless of enormous progresses made in the field of learning style, there is not a single consensual definition or macro-level theory to describe learning styles. Of course, the different definitions and explanations of learning styles have commonalities and unique qualities (Dunn & Griggs, 2000). If one looks at the dictionary meaning of the term learning style, it stands for individual differences in the way that people prefer to learn (Frisby, 2005). It is further described that learning styles is a unique pattern that individuals use to approach information processing or learning situation. Frisby (2005) explains that the way people think, learn, and process information is unique and often influenced by their attitudes, feelings, and preferences. Hence, teachers and/or classroom instruction needs to be individualized and sensitive to different learning styles.

In general, literature shows that there are more comprehensive and loose, narrower and focused definitions and models of learning styles. Dunn and Griggs further justified that many theorists such as (Kolb & Kolb, 2005; Kolb, 1981) focus only on a single or two variables in bipolar continuum. However, others argue that "the complex nature of learning

suggests that a multidimensional model is required to reflect the many individual differences resulting from each person's biological, developmental, and psychological experiences. Thus, "a multidimensional concept of learning style is the basis of these comprehensive models" (Dunn & Griggs, 2000, p. 8). Hence, applying the same teaching method may be effective for some learners but ineffective for others (Dunn, et al., 2002).

Receptive learning styles

According to Felder and Silverman (1988), people have different strengths of Visual/Verbal and Sensing/Intuition receptive learning styles profiles. In different literatures, these receptive learning styles may alternatively be termed as sensory modalities or perceptual learning channels (Kratzig & Arbuthnott, 2006). Accordingly, Felder-Silverman (1988), define Visual/Verbal learning style dimension as the preferred channel of input collection or stimuli. For instance, verbal learners prefer information presented verbally in written or auditory form, while visual learners take in information most effectively when it is presented visually in a diagram or picture form, such as components of an electric circuit. The Sensing/Intuitive receptive dimensions of Felder-Silverman LS dimension may be referred to as perceptual preferences. Sensing learners prefer to perceive concrete experiences, facts, details; whereas intuitive learners prefer to perceive abstract ideas, meanings, theories and imagination.

Information processing styles

Information processing learning styles directly related to the way we process information received through sensory modalities. The acquired information can be processed and transformed into knowledge through information processing styles such as Active/Reflective style (Felder & Silverman, 1988; Kolb, 1984), Sequential and Global styles (Felder & Silverman, 1988; Feldman, 2003). For example, learners with most sequential learning style learn most easily when they are first taught with information individually (Felder & Silverman, 1988; Feldman, 2003). However, learners with global learning style learn readily when they are exposed to the full range of material first so that they break it down into its component parts (Felder & Silverman, 1988; Feldman, 2003). Thus, to accommodate learners with different learning styles instructional materials need to be designed not only based on the nature of the subject but also based on learners' ways of learning.

Learner achievement

The constructs "academic achievement" and "academic performance" are often used in manners that create confusion in reference to the different levels of measurable and observable behaviour of learners. It is hardly surprising that there seems to be a lack of consensus among researchers regarding the similarities and differences among the constructs: academic achievement and academic performance. One of the major conceptual problems of this measurement constructs in educational research is that on one hand they mean different things to some researchers and to others they mean the same thing.

Achievement is defined as measurable behaviour in a standardized series of tests (Simpson &Weiner. 1989). The tests are usually constructed and standardized to measure proficiency in school subjects. The most highly valued method of determining whether a successful completion has taken place for a learner is quantitative in nature. In other words, numbers are used to indicate whether a learner has been successful or unsuccessful in mastering academic content and skills (Simpson &Weiner, 1989).

According to Bruce and Neville (1979), "accomplishment" is sometimes used in place of "achievement", as educational achievement is measured by standardised achievement test developed for school subjects. What this means is that academic achievement is measured in relation to what is attained at the end of a course or subject, since it is the accomplishment of medium or long term objective of education. What is important is that the test should be a standardised test to meet national or state norm. For a test to be standardised, it must be valid for over a period of time.

According to Steve (2000), academic achievement is distinguished from academic performance in that academic achievement is long-term (end‘) while academic performance is measurable at any point in time (continual‘). In other words, achievement can be measured as stagnating, falling or improving over a long period. Steve (2000) further classified activities that occur in performance as academic performance index, for instance, learners' performance based on reading, selection of one or more schools within each district, among others. According to Steve (2000), satisfactory academic achievement award is given to recipient who maintains satisfactory academic performance and progress towards, the attainment of high school certificate. This is to suggest that academic achievement is cumulative and progressive: it means that academic achievement cannot be attained within a short period of

time. What this indicates is that academic performance culminates and influences academic achievement.

Performance is defined as the observable or measurable behaviour of a person in a particular situation usually experimental situation (Simpson & Weiner, 1989). This means that performance measures the aspect of behaviour that can be observed at a specific period. To determine performance, a performance test is conducted. Steve (2000) defined performance test as the type of mental test in which the subject is asked to do something rather than to say something. In relation to educational research, academic performance of a learner can be regarded as the observable and measurable behaviour of a learner in a particular situation. For example, the academic performance of a learner in physical science includes observable and measurable behaviour of the learner at any point during a course. Therefore, we can equate academic performance with the observed behaviour or expectation of achieving a specific statement of or statement of educational intention in a research. Academic performance of students consists of scores obtained from teacher-made test, first term examination, mid-term test, and so on (Steve, 2000).

Academic achievement has always been influenced by the learner‘s previous education performance (Bratti & Staffolani, 2002), parents’ income and social status (Considine & Zappala, 2002), student‘s social and emotional status or wellbeing (Erdogan, Bayram, & Deniz, 2008), the school environment (Sentamu, 2003), among other factors. This study aimed at determining the relationship between learning styles and academic achievement. An experimental research was therefore conducted to examine the causal-effect relationship between the two variables so as to confidently and empirically state whether or not learning styles determines achievement in education.

Teacher instructional practices

In attempting to give meaning to the concept instructional practices, it is rational to give a description of the term ‘*instruction’*. Traditionally, instruction has been viewed as a set of components used to support the internal processes of learning (Hodges, 1980). Gagne and Briggs (1974, p.135) define instruction as:

> “Making progress from one moment to the next during a lesson, a set of events takes place which acts upon the students, and in which he becomes involved. The set of

events is specifically meant by "instruction". These are the events that are usually external to the learner, supplied by the teacher, or text, or other materials with which the learner interacts".

This definition implies that instruction encompasses the whole process of planning, communicating information to the learners and stimulating relevant learning activities. The term *instruction* has been used synonymously with *teaching* (Bruner, 1966). To Eze (2011), teaching is the *how* and the *way* that the curriculum is taught. A teacher can deliver instruction in ways that make it approachable by all learners. The teacher uses the curriculum to design the instruction that, hopefully, causes learners to learn. The definition by Gagne and Briggs (1974) suggests that instruction should be taken to mean all that is done by the teacher during the teaching and learning process to support and facilitate learners' learning. In this view, instruction encompasses the whole process of communicating information to the learners, planning and stimulating relevant learning activities and assessing and evaluating the effect of those activities (Visser, 2007). Instruction can take place in the absence or presence of the individual called a teacher. This conception of teaching accepts that teaching is part of instruction and instruction is the broader and more encompassing concept. Taken in this sense, the presence of the teacher becomes a pre-requisite for the occurrence of teaching (Schwier, Campbell, & Kenny, 2004).

Pertinent review of literature in science education (Tsai, 1999; Wetzel, 2012; Windschitl, 2004) suggests that the concept *instructional practice* is in itself indefinable. The concept *instructional practice* has been associated with the terms strategy, approach, style, method, skills and technique. The terms approach, strategy technique and method sometimes overlap. In some instances the terms can be adapted to refer to teaching styles and teaching skills. In this study, the terms are used synonymously, bearing in mind that each one might take an idiosyncratic distinction depending on context. Instructional practice is a summation of what the teacher does and what the learners do during the teaching and learning of any science content.

2.9.1 Establishing the link between theory, the research problems and research questions

This section provides an overview of how research questions relate to the theories that were discussed so far and how that addressed what was perceived to be the four problems that the study undertook.

The researcher drew from the learning style theories, brain-based learning theory and constructivist views of learning and teaching as well as cultural border crossing theory to investigate these five research questions (see section 1.4). Thus, the researcher viewed learning-style based instructions as an educational tool that science teachers could use to design instructions to facilitate learning as well as a tool that the learners themselves could use to make meaning and to receive and process information during lessons in order to improve their academic achievement in the subject.

The researcher therefore, wanted to understand how learners' learning style-based instructional strategies could be used to mediate learning at different learning style domains and preferences.

This study therefore, focused on four problems:

The first problem was related to the most common modes of receiving and processing information in today's learning situation. Drawing from the researcher's experiences as a science teacher and through extensive reading about the differences learners bring to the classroom, the researcher needed to identify the different learning style preferences among learners. Therefore, the first research question aimed to address the first problem: to identify the prevailing learning style preferences among learners. Thus, "With regards to the learning style index, what are the prevailing learning style preferences that are common among these learners?" With this question in mind, the researcher sought to identify the learning style preferences among learners in the science classroom. This was done by distributing index of learning style questionnaires to learners to determine and identify their learning style preferences.

The second problem was related to the most common cultural attributes of learning that learners share in the five schools and how this knowledge can be used to determine learners' learning styles. Widespread studies (for example, Cole, Gay, Glick & Sharp, 1971; More, 1990) reveal a strong link between culture and learning style. The experimental anthropological findings of Cole et al. (1971) uncover the relationships between culture and how people think. More (1997) sees this as being closely linked to the phenomenon of cultural patterns and learning styles. Related studies (for example, Berry, 1976; More, 1996)

suggest that ways of learning and the learning style one favours are fundamentally learned from relatives and close family friends. It is here that the child learns content and skills as well as how to learn. For that reason, the researcher needed to understand the common cultural attributes that learners share and how culture could influence learning style preferences among learners. The second research question therefore, aimed to address this problem; to know common cultural attributes of learners and to understand the influence of cultural attributes on learning style.

The third problem was related to the alignment of teaching styles to learners' learning styles. The mismatch with learning and teaching styles was identified as a factor for learners' underperformance (Tyndall, 2015). Several researchers (Felder & Silverman, 1988; Naimie, Siraj, Piaw, Shagholi, & Abuzaid, 2010) noted that students are not performing well at schools because their preferred ways of learning are usually in contrast with their teachers' teaching styles. Thus, the third and fourth research questions aimed to address the third problem by aligning teachers' teaching styles to learners' learning styles in the science classroom.

The fourth problem was related to the fact that academic achievement has, for the past decades, been the centre of interest in most scholarly inquires. Investigating the issue of performance has stretched further than simple issues of intelligence and prior academic achievement into how learners interact with the learning material. There is a general consensus that the manner in which individuals choose to approach a learning situation has an impact on the performance and achievement of learning outcomes. Utilising awareness of learning style within the educational background promotes more effective learning and hence improved academic achievement. The fourth and fifth research questions targeted this problem: "What impact, if any, does the learning style preference of learners have on their academic achievements?" and "How can students' academic achievements in physical sciences be explained by the use of learning style-based instructional strategies in the science classroom?"

To answer these questions, the researcher identified the patterns of learning style preferences among the learners. Thus, to accommodate learners with different learning styles, instructional materials needed to be designed not only based on the nature of the subject but also based on learners' preferred ways of learning, to be implemented in the science

classroom to improve learner performance in physical sciences.

2.10 Studies related to learning style preferences on learners' academic achievement

A significant number of studies have been carried out to establish whether learning style preferences have any influence on learners' academic achievement. Considerable number of previous research has sought to bring into being the link between learning style and academic achievement. Bosman and Schulze (2018) investigated the correlations between mathematics achievement outcomes and LS, as well as the learning styles of high and low achievers. The study employed quantitative design comprising 240 learners from one high school in South Africa. The findings show that a student's learning style correlated the highest with mathematics performance. The study recommends teachers to create an encouraging learning environment at school and utilise teaching approaches that accommodate a diverse learning styles.

Lu and Yang (2018) investigated the relationship between learning style, concentration and achievement of students in terms of visual/verbal learning when learning conceptual knowledge with the use of mobile phones in the classroom. A total of 93 Chinese college students who majored in education participated in this study. The finding shows a significant interactive effect on learning achievement on visual/verbal learning style and concentration

Tyndall (2015) investigated the adaption of instructional methodology when aligned to students' common learning styles on student performance in a sociology course. The community college associated with the current study has been having limited student success for the past 15 years. The Felder-Silverman Learning Styles model was used as the theoretical framework for the current study. Participants completed the Index of Learning Styles (ILS) questionnaire to capture information on their learning styles. Appropriate teaching styles were adapted to participants' common learning styles. The comparison of participants' midterm and final examination grades revealed that participants earned higher grades on the final examination because of the intervention in the second half of the course.

Jahanbakhsh (2012) investigated the relationship between learning styles of high school girls and their academic achievements based on their majors in Iranian high schools. The study followed a non-experimental descriptive survey design. A population of 350 individuals were selected as sample of the study by a multi-stage random sampling. A Felder-Silverman's

ILSQ and tests were used to collect data. Data were analysed statistically using Pearson correlation coefficient and multiple regressions. The results indicated that sensing/intuitive learners showed a significant correlation (0.01 levels) with the academic achievement of students whose major was mathematical science. Sensor style shows a negative correlation (-0.238) while intuitive style shows a positive (direct) correlation (0.238). Similarly, the active/reflective LS showed significant correlation (0.01 levels) with the academic achievements of students whose major was speculative science. Active LS learners showed a reversed correlation (negative correlation) while reflective LS learners showed a direct link (positive correlation). The academic achievement of those whose major was empirical science also showed a significant correlation at 0.01 levels with both visual/verbal and sequential-global LS.

In another study, Orhun (2012) investigated the relationship between learning styles and achievement in calculus course for engineering students. The subjects were third semester students (n=87) who enrolled in Anadolu University Engineering Faculty (Turkey) in the fall term of 2009. The study followed a non-experimental design and data were collected using Kolb's Learning Style Inventory (LSI) and students' grades of achievements acquired in calculus. Data were analysed statistically using sample t-test and one-way analysis of variance (ANOVA). The findings showed a statistically significant difference between calculus achievement and learning styles.

Gappi (2013) explored the student's preferred learning styles and achievement to describe the learning style preferences of the student to find out whether learning style preferences of the students differed with age, gender and academic program; and to determine the relationship between the learning style preferences and the learners' academic performances. 131 freshmen who were accepted during the first trimester of the academic year 2012/2013 were used for the study. The sample comprises 118 national youth and 13 young adults. FSILSQ questionnaire was utilised to conduct the study. The results revealed that the students are fairly well balanced on the entire four LS dimension. The study further revealed that there was no significant influence of gender, age and academic performance on the LS preferences of the students.

A similar study conducted by Vaishnav and Chirayu (2013) on the analysis of learning styles prevalent among secondary school students also investigated the relationship and effect of

different learning styles on academic achievements of students. It was conducted on three learning styles, visual, auditory and kinesthetic (VAK). A sample of 200 students of 9th, 10th and 11th class standard of Maharashtra State was randomly selected for the study. After selecting the sample, Howard Gardner's VAK learning style brain box and VAK Learning Style Inventory by Victoria Chislett and Alan Chapman were used to identify the preferred learning style of students. The correlation between academic achievement and learning style was determined using Pearson's product moment co-efficient of correlation method and also ANNOVA F test was used to identify the effect of learning style on academic achievement. Findings of the study revealed that a kinesthetic learning style was more prevalent than visual and auditory learning styles among secondary school students and there was a correlation between kinesthetic LS and learners' academic achievement. The other two learning styles have a weak positive relationship.

Gokalp (2013) evaluated the learning styles of education faculty students and determined the relationship between their learning styles and academic success. The findings indicated a significant difference between the scores of pre-tests and post-tests. This implies that the students learned how to study effectively. The study found that statistically significant differences existed between the results of the first and final applications of the sub-tests on learning styles and academic success. Even though these studies were carried out with the focus on the diversity among LS models, the results show a positive relationship between learning styles and academic achievement regardless of the model used. It is inevitable that diverse assessment instruments of learning styles exist.

In contrast, Cimermanová (2018) investigated whether learning styles of students and the form of teaching generate interactive effects on their learning achievements. Cimermanová employed Grasha-Riechmann Student Learning Style Scales (GRSLSS) inventory to determine LS of the sample subjects and a pedagogical quasi-experiment was employed for Five months. The study employed a convenience sample of 81 fifth year university students. The students were randomly assigned to control and experimental groups. A two-way analysis of variance of the quantitative data showed no significant findings. The results indicate that the LS and type of teaching strategy have no effect on academic achievement.

Gakhar (2006) studied the academic achievement of students as determined by their preferred learning and thinking styles, and study skills. The study aimed to find out the differences in

the academic achievement of the students due to different learning styles, different thinking styles, and low and high levels of study skills. This survey study was conducted on a sample of 136 final year BPT students taken from three states: Punjab, Haryana and Delhi. The instruments used were: 1) Group Test of General Mental Ability; 2) Socio-Economic Status Scale; 3) Style of learning and thinking; 4) The Cornell Learning and study skills inventory; and 5) Academic Achievement as measured by taking aggregate marks of BPT I, II and III years from their college record. The findings established that there was no significant difference in the academic achievement of students with active and verbal LS, divergent and convergent LS, content preference for open-ended lessons and structured lesson LS

Yilmaz-Soylu and Akkoyunlu (2009) study on the effect of learning styles on academic achievement in different learning environments showed no significant differences between students' achievement levels and their learning styles.

Therefore, the studies by Cimermanová (2018), Gappi (2013), Yilmaz-Soylu and Akkoyunlu (2009) and Gakhar (2006) showed different results from the studies conducted by Bosman and Schulze (2018), Lu and Yang (2018), Tyndall (2015), Jahanbakhsh (2012), Orhun (2012) and Gokalp (2013).

2.11 Studies related to learning styles and learning style-based instructional designs on achievement

Research studies have substantiated the need for identifying learners' preferred learning styles and for instructional strategies that complement those styles. Lamidi, Oyelekan and Olorundare (2015) believe that science and technology cannot thrive without the use of appropriate instructional strategies to enhance learners' performances in the subject. Felder (1988) posits that the quality of science education could be significantly enhanced if teachers modify their instructional strategies to accommodate the learning styles of all the learners in their classes. Thus, teachers' would have to continually vary their instructional methods in the science classroom to ensure active learning.

Farks (2003) measured the effect of traditional and learning styles instructional methods on middle school students. The study found that learning styles-based approaches to the curriculum resulted in achievement, attitude and transfer levels significantly greater than those realised with traditional approaches. Marković and Jovanović (2012) agreed that the

quality of education will be enhanced significantly if teachers modify their teaching strategies to accommodate their learners' learning styles.

Dasari (2006) studied the influence of matching teaching and learning styles on the achievement of grade 6 learners in science in Qatar. The objective of the survey was to explore whether there is a significant difference in the academic achievements of grade 6 science learners when the teaching strategy was matched to their learning styles. A quantitative approach was undertaken. The population comprised sixth grade learners selected according to a non-probability sampling method of convenience. The sample included 87 learners between 11 and 13 years. The data were collected by the use of Learning Style Inventory developed by Connor (2005) and a science unit of enquiring written test on units Alkynes and electricity, which were constructed by the researcher. The data were analysed by the dependent t-test. The outcomes of the survey revealed a significant difference in the science achievements of sixth grade learners when teaching style was matched to learning style.

Gohel (2009) explored the effect of learners' learning style-based instructional strategy on science achievement of secondary school learners. His study found that varied instructional strategies under visual, auditory and kinaesthetic learning styles impact significantly on the learners' academic achievements in science.

2.12 Chapter summary

In this chapter, the literature that informed the study was critically reviewed. The chapter began with the conceptualisation of learning styles. The theories on the concept of learning styles were explored and then analysed in more depth while several learning style theories and models were examined. The chapter then continued with a description and discussion of the three key theoretical frameworks: constructivism, brain-based learning theory and approaches to learning styles. The chapter also gave a brief overview of the criticisms which have been levelled against the use of learning style models. The chapter ended with the review of research studies on learning styles, learning style-based instructions and its influence on learner academic achievement.

In the next chapter, the research methodology, founded on the literature and employed in the study to answer the research questions will be described and discussed.

CHAPTER THREE
THE METHODOLOGY

3.0 Introduction

This study aimed to design and implement a mixed methods research study. A mixed-methods design was necessary because the researcher aimed to explore the impact of learning style-based instructions on learner achievement by considering learners' cultural backgrounds. This phenomenon is multifaceted and requires multiplicity of knowledge sources which were blended with the research questions to construct a meaningful proposition about the complex environment of learning styles and learning style-based instructions on achievement in schools in Mthatha. Its central idea was that combining quantitative and qualitative approaches in one study was necessary as it provided statistical evidence and a better understanding of research problems than either approach alone.

The main research question was:

> What is the relationship among learners' learning style preferences (considering learners' cultural backgrounds), teaching styles, learning style-based instructions and learners' academic achievement in physical sciences among grade 11 learners in Mthatha high schools?

The following sub-questions emanate from the main research question and served to guide the study:

(1) With regards to the learning style index, what are the prevailing learning styles that are common among these learners?

(2) How can knowledge of the cultural attributes of learning be used to determine the most likely learning style favoured by learners?

(3) What relationship (if any) exists between the teaching styles currently used by teachers sampled for the study and the most common learning style of their learners?

(4) What impact, if any, does a learning style-based instruction have on learner academic achievement in physical sciences?

(5) To what extent and in what ways do the learning style-based instructions impact on learners' and teachers' experiences towards teaching and learning?

Hypothesis (H_o)

Therefore, the following null hypotheses were formulated and tested at significant levels:

- (H_o1): There is no significant difference between the mean pre-test and post-test scores for grade 11 learners in the control group.
- (H_o2): There is no significant difference between the mean pre-test and post-test scores for grade 11 learners in the experimental group.
- (H_o3): There is no significant difference between the mean post-test scores for learners in the control and the experimental group after controlling the effect of pre-test scores.
- (H_04): There is no significant relationship between learning styles and learners' academic achievement in physical sciences.

3.1 Research paradigm

A research paradigm, according to Kuhn (1962), is "the set of common beliefs and agreements shared between scientists about how problems should be understood and addressed" (p. 172)**.** Ling and Ling (2017) explain that a paradigm refers to a world-view or a high-order way of thinking about or categorising the approach or logic that underpins all aspects of a research undertaken from the intent for the study to the final design, conduct and outcomes of the study. Similarly, Blaikie and Priest (2017) contend that a research paradigm offers alternative ways of addressing research problems. Thus, they are like different tools for different tasks and they provide a range of possible ways of approaching and investigating a research problem.

For educational researchers, there are several major paradigms that govern their inquiries into the policies and practices of education. Each paradigm carries its own assumptions, philosophies, ontologies, epistemologies and methodologies. For example, Punch and Oancea (2014) identify two major paradigms (positivist and interpretivist) while Fischer, Boone and Neuman (2014) propose three major paradigms (positive, interpretivist and critical social science paradigm). Pragmatism is another branch of research paradigm that refuses to join the

"paradigm war" between the positivist and interpretivist research philosophies (Teddlie & Tashakkori, 2003). The key features of these philosophical perspectives that include the world-view, the nature of information determined and the different ways by which information is created and evaluated within each paradigm world-view are discussed below. Nonetheless, there is no agreement as to whether these research paradigms are necessarily opposed or whether they can be seen to have a different role in the same study.

On the whole, the difference in philosophical paradigms raised the question of whether the current research should be addressed by a single research approach or by more than one approach.

3.1.1. Philosophical assumptions adopted in this study

Scholars base their research on definite philosophical viewpoints that are grounded on a distinct paradigm(s), subject to their field and area of study.

The research problem, the related research objectives, and accompanying research questions are multifaceted in nature. For this reason, both qualitative and quantitative approaches were selected for this study. Hence, the combination of research approaches led to the adoption of a pragmatic paradigm in this research.

Pragmatism, according to Tashakkori and Teddlie (1998), is defined as

> "a deconstructive paradigm that debunks concepts such as truth and reality and focuses instead on what works as the truth regarding the research questions under investigation" (p. 713).

McCoy (2015) pointed out that pragmatism advocates for the use of mixed methods in research and acknowledges that the value of the mixed-methods approach plays a large role in the interpretation of results. Mixed methods research, according to Burke, Onwuegbuzie, and Turner (2007), is an approach to knowledge that considers multiple viewpoints, perspectives, positions and standpoints (always including the qualitative and quantitative standpoints). Creswell (2005) defines a mixed-methods design as a procedure for collecting, analysing, and incorporating both quantitative and qualitative data in a research to achieve an enhanced empathetic of the research problem. Rauscher and Greenfield (2009) explain that mixed-methods research seeks to build on the strengths and reduce the flaws of both qualitative and

quantitative approaches to draw inferences which can lead to an increased understanding of the topic being researched.

In this study, mixed-methods research was employed to answer the research questions. This was because the researcher aimed to explore the impact of learning style-based instructions on learner achievement by considering learners' cultural backgrounds. This phenomenon is multifaceted and requires a multiplicity of knowledge sources, including experiential, epistemological and ontological views, which were blended with the research questions to shape and direct the study. In addition, mixed-methods design was used to develop analysis to provide rich data which included: exploring the reasons why teachers adopt certain methods of instructions; hearing the concern of learners and teachers (with regards to teaching and learning); understanding the existing relationships among variables (learning styles, learning style-based instructions, cultural attributes and achievements).

The richness of the mixed-methods research is supported by Tashakkori and Teddlie (1998) They highlighted three areas in which mixed methods are superior to single approach designs: (a) mixed-methods research can answer research questions that the other methodologies cannot answer; (b) mixed-methods research provides better inferences; and (c) mixed-methods research provides the opportunity for presenting a greater diversity of divergent views. Furthermore, the choice of a mixed-methods research for this study helped the researcher: (a) to ascertain and to handle threats for validity emerging from the use of the design; and (b) to achieve a broader perspective and profound understanding of learning style-based instructions in relation to cultural background and their impact on learner achievement. Jones and Sumner (2009) stated that implementing mixed-methods research enables the researcher to explore, contradict and even refute phenomena, by providing a fuller and richer picture of the research phenomenon. This approach was chosen for the study to construct a meaningful proposition about the complex environment of learning styles and learning style-based instructions in schools in Mthatha. Its central premise was that the use of the quantitative and qualitative approaches in combination provided a better understanding of this study's problem than either approach alone.

The literature (for example, Akinbobola, 2015; Manikutty et al., 2007) provided studies on learning styles, cultural attributes, learning style-based instructions and academic achievements but not through a combination of quantitative and qualitative methods. A

mixed-methods research explored the concepts more fully than other studies and allowed for a detailed understanding of learning styles, learning style-based instructions and academic achievements. Hence, Sammons, Siraj-Blatchford, Sylva, Melhuish, Taggart, and Elliot (2005) argue that studying school-related matters requires analysis that is informed by multiple and diverse perspectives of philosophy because of their complex and pluralistic social contexts. Hayes (2015) affirms this and posits that the mixed-methods enable the researcher to get an in-depth knowledge about the study. Entwistle and Ramsden (1983, p. 6) refer to the "importance of trying to marry qualitative and quantitative methods of research" and to their main concern "to use both quantitative and qualitative methods for collecting and analysing data". They note that qualitative methods such as semi-structured interviews are one of the hallmarks for understanding student learning, but that more traditional quantitative techniques can be incorporated and can enrich the understanding of the concept under study.

Although this design was chosen for this study, it also has its own weaknesses. According to Morse (1991), a mixed-methods design takes much time and many resources to collect and analyse both types of data. Hence, there was the need for extended research time in order to deal with the large number of instruments used and to consider research design issues such as potential bias in the data integration, logistical issues in conducting the research and demonstrating the rigour of the supplemental data. The design also requires skills and hence the need to develop new skills - it is critical that researchers are aware of their skills sets and whether they are able to cope with the demands of utilising a mixed methods approach (Creswell & Plano Clark, 2011). Finally, and in many ways the most pressing challenge, is that of deciding which mixed method research design is most appropriate for a particular study. This depends entirely upon how the researcher feels about where the project lies on the continuum of research approaches—will the approach be purely mixed method which gives equal status to both quantitative and qualitative information or will it be dominated by one approach or the other (Burke, et al., 2007)?

As such, it was possible to overcome and address these limitations through assimilating subjective bias into the research process which contributed to and strengthened the research instead of crippling it, as noted by Seedat (1992). For this study, the approach taken was appropriate because learners' and teachers' perceptions on learning styles were inherently unknown at the beginning of the study.

3.2 Research methodology

Method in research includes the sequential steps adopted in studying a problem with certain objectives. Myers (2009) defines research method as a strategy of enquiry that moves from the underlying assumptions to research design and data collection. The success of any research depends upon the suitability of the method adopted for the purpose and scope of the study. The decision about the methods or methods to be employed always depends upon the nature of the selected problem and kind of data needed for its solution.

Even though there are further differences in the research approaches, the utmost common classifications of research methods are qualitative and quantitative. On one hand, qualitative and quantitative refer to discrepancies about the nature of knowledge, how one comprehends the world and the ultimate drive of the research. On the other, the terms refer to research approaches, that is, the way in which data are collected and analysed, and the type of generalisations and illustrations resulting from the data

Quantitative and qualitative approaches can also be understood by contrasting the differences between two philosophical positions about the state of reality: positivism and constructivism. Quantitative research, embraces positivist view of the world; it proposes that reality is somewhat perceptible that can be measured objectively with the help of observational and investigative methods. Qualitative research follows constructivist worldview that suggests that reality is in the eye of the beholder (Kielmann, Cataldo, & Seeley, 2012). In other words, there is no single reality for a given phenomenon, but multiple, relative dimensions of reality which can only be partially captured using subjective, naturalistic methods (p. 7).

Quantitative research methods were originally developed in the natural sciences to study natural phenomena. Quantitative researchers measure variables on a sample of subjects and express the relationship between variables using effect statistics, such as correlations, relative frequencies, or differences between means. Their focus is on the testing of theory. Qualitative research methods were developed in the social sciences to enable researchers to study social and cultural phenomena. According to Domegan and Fleming (2007), “qualitative research aims to explore and to discover concerns about the problem on hand, because very little is known about the problem”.

While quantitative research presents statistical results represented by numerical or statistical

data, qualitative research presents data as descriptive narration with words and attempts to understand phenomena in "natural settings". According to Denzin and Lincoln (2000), qualitative researchers study things in "their natural settings attempting to make sense of, or to interpret, phenomena in terms of the meanings people bring to them" (p. 3). Hittleman and Simon (1997) believe that "quantitative research makes use of questionnaires, surveys and experiments to gather data that are revised and tabulated in numbers, which allows the data to be characterised by the use of statistical analysis" (p. 31).

Both quantitative and qualitative research studies are conducted in education. Neither of these methods is essentially better than the other; their appropriateness in a study desires to be decided by the setting, drive and nature of the study. Brysman and Burgess (1999) note that some researchers prefer to use both quantitative and qualitative methods in a single study to take advantage of the differences between both methods. Since the present study aimed to find the cause/effect relationship of learning style-based instructions and their impact on learner achievement, it was found that both quantitative and qualitative methods were suitable for the study for the following reasons:

- The research problem (see section 1.2) is best understood by collecting diverse types of data in the form of a combination of quantitative and qualitative research methods (Woodwell, 2014).

- There is an assumption that the data received will be more valid due to the process of triangulation. Struwig and Stead (2013) defined triangulation as an attempt to compare data which are obtained using two (quantitative and qualitative) or more methods of data collection. If different research methods produce data that are more or less the same, then the process of triangulation will show the researchers that they can be confident that their findings are accurate (Dahlberg & McCaig, 2010). In this research, triangulation of methods was achieved by using quantitative data collection methods in the form of a structured questionnaire and qualitative methods in the form of individual interviews and classroom observations.

- While quantitative data were gathered to establish the extent and nature of the problem under investigation, the qualitative data were gathered to help the researcher to explore the perceptions, perspectives and attitudes of respondents to the research

problem. This data cannot be captured fully in a quantitative survey so in-depth semi-structured interviews and observations were carried out to have a profound understanding of the issues of learner performance (Kostere, Kostere, & Percy, 2009).

- It compensates for the weaknesses of the different research methods (quantitative and qualitative) being used (Denscombe, 2007).

3.3 Research design

The Felder and Silverman (1988) learning style model influenced the current research design, data collection process and data analysis procedures. The research design is a strategy that is used for solving a research problem. According to Leedy and Ormrod (2013), a research design provides the overall structure for the procedures the researcher will follow, the data the researcher will collect and the data analysis the researcher will conduct. Before a researcher decides which research design to use, he/she needs to look at what kind of study will be done and what type of study will best answer the questions that have been formulated. The focus must therefore be both on the point of departure (the research problem and question) and on the end product (the kind of results being aimed at). For that reason, the focus of the research design is always on the logic of the research (Neuman, 2006) and the kind of evidence that is required to address the research question adequately.

The mixed-method approach was employed in this study, specifically, a mixed-methods sequential explanatory design that consist of quantitative and qualitative phases. According to Creswell (2009), the sequential explanatory mixed-method design consists of quantitative data collection and analysis, and this is followed by the qualitative data collection and analysis. This helped explain or elaborated on the quantitative results obtained in the first phase. The second qualitative phase built on the first quantitative phase, and the two phases were connected in the intermediate stage of the study (Ivankova, Creswell, & Stick, 2006a) to complement each other.

The rationale for this approach was that the quantitative data and their subsequent analyses provided a general understanding of the learners' learning style preferences in relation to their academic achievements, considering the teachers' instructional strategies. According to Creswell (2003), the qualitative data and their subsequent analyses refined and explained statistical results, by exploring participants' views on learning style-based instructions in

more depth. The study is also correlational in that the relationships between learning style, learning style-based instructional strategies and learner academic achievement are examined. SPSS was used to calculate descriptive and correlation statistics from the data collected at the commencement of the study and at the end of the intervention. Critical insights come from summaries of learners and teachers' written responses at the end of the intervention. Although the philosophical distinctions between qualitative and quantitative research has become blurred, the difference between the two approaches remains technical. Due to these differences the two methods can be used in complementing each other rather than competing against one another. In this study the interview that took place after the completion of the questionnaire acted as a complement to uncover the reasons why learners answered the questions the way they did.

The figure below summarises the sequence of research activities followed in this study. The figure shows all the data collection and analysis procedures, and lists the outcomes from each of the stages of the study. It also shows the integration of the quantitative and qualitative phases.

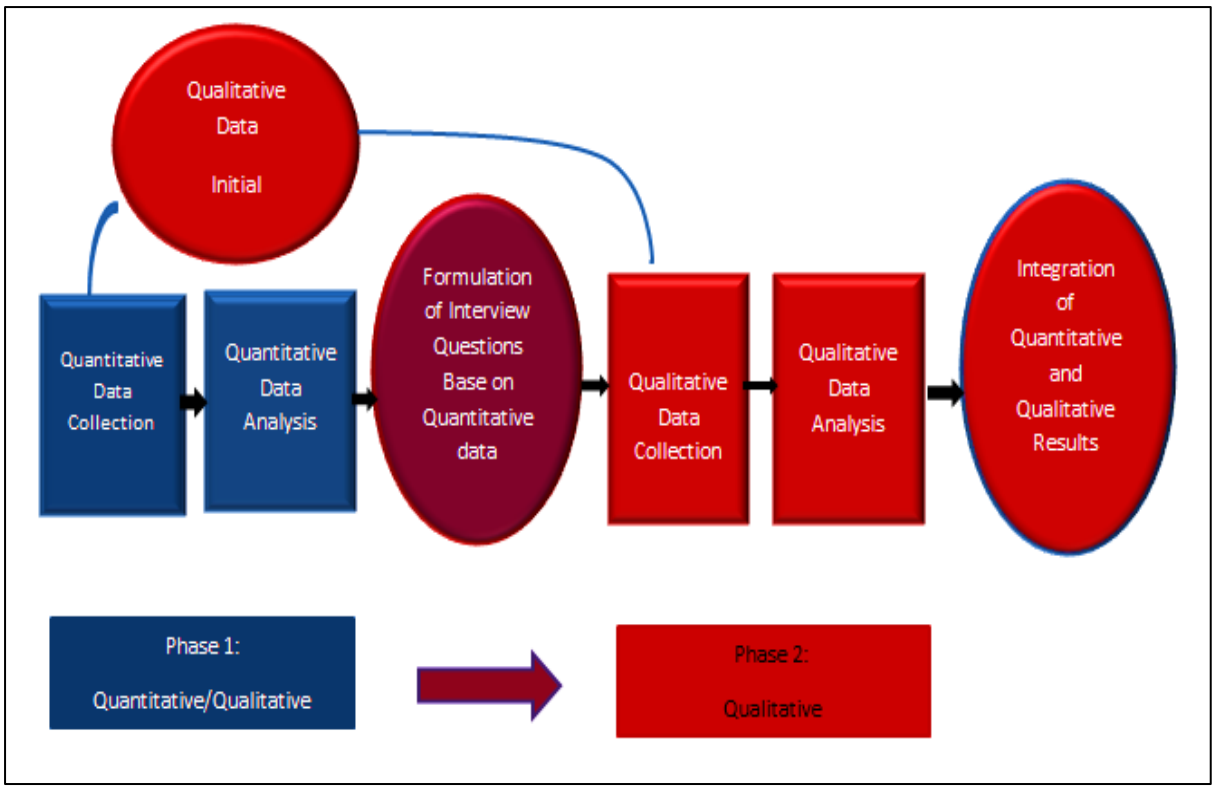


Figure 3.1: Sequential Explanatory Mixed-Methods Design
Source: Adapted from Creswell (2009)

In the quantitative phase, the researcher employed an experimental research design. According to Fischer, Boone, & Neumann, 2014), experimental research designs are those set-ups in which one group is treated in a particular manner and the expected outcomes are compared to data and measures collected from a control group which receives a different treatment. McMillan and Schumacher (2010, p.258), state that experimental research is characterized by "theory driven research hypotheses, random assignment of subjects, manipulation of independent variable, measurement of dependent variable, use of inferential statistics and control of extraneous variables".

Even though the experimental research treasures its greatest service in the laboratory, it has been successfully implemented in non-laboratory environments, such as the classroom, where major variables can be measured and controlled to some extent. In this study, the researcher measured the impact of teachers' instructions on learner outcome in a topic in physical sciences, by training teachers on how to design and implement instructions for learners in the experimental group, while the teachers in the control group received no training in the design and implementation of instructions. This was to help the researcher to decide if the measured

effect is a result of the treatment.

McMillan and Schumacher (2010, p.19) categorised experimental studies into three types. Namely:

- True experimental design
- Quasi-experimental design
- Single subject design

In this study, quasi-experimental design was employed. Although, quasi-experimental designs have an intervention and manipulation of the independent variable, they lack a key feature of experimental study – randomisation (Baker, 2017).

Quasi-experimental design

In a quasi-experimental design, the researcher does not randomly assign participants to comparison groups usually because random assignment is not feasible (McMillan & Schumacher, 2010). However, the main purpose of a quasi-experimental design is to determine cause and effect (McMillan & Schumacher, 2010). A common situation for implementing quasi-experimental research involves research in which several classes or schools are used to determine the effect of teaching methods. In such a situation, it is possible to give an intervention to some of the classes and treat other classes as the control group (McMillan & Schumacher, 2010).

The study employed a quasi-experimental non-equivalent control group design that consisted of a pre-test/post-test control group to measure learners' learning outcomes in electricity and magnetism before and after treatment. According to Best and Kahn (2007), this design is often used in classroom experiments when experimental and control groups are naturally assembled groups as intact classes which may be similar. This design was considered appropriate for this study as it allowed for comparison of the experimental and control groups, manipulation of independent variable, measurement of dependent variable, use of inferential statistics and provide for maximum control of extraneous variable (McMillan & Schumacher, 2010). Although this design is not as strong in controlling for threats to internal and external validity as in a true experimental design, however, the hallmark of a good quasi-

experimental design study is that the researcher has instituted controls and sometimes a more natural setting is advantageous (Baker, 2017). Hence, this research design was preferred because it permitted the researcher to determine changes in learner achievement after exposure to a treatment and the impact that the treatment had on the learners. Thus, this design can show the effect of an intervention as well as associations and trends. The research design is given below.

Table 3.1: Design for experimental and control groups

GROUPS	PRE-TEST	TREATMENT	POST-TEST
EXPERIMENTAL	O_1	X	O_2
CONTROL	O_3	-----	O_4

The experimental group represents the classes in which the teachers implemented instructional strategies that matched learners' learning styles (X) in the teaching of the topic "electricity and magnetism". The control group represents the class for which the traditional teaching approach (---) was used in the teaching of the topic "electricity and magnetism".

O_1 and O_2 represent the pre-test that was administered to all the groups at the beginning of the study. O_3, and O_4 represents the post-test that was administered to all the groups at the end of the treatment period. The independent variable manipulated in this study was the teaching strategy which differed in the experimental and control group. The dependent variable measured due to the different teaching strategies was the test scores of the groups in the post-test. The pre-test and post-test scores for the groups were then compared for any statistically significant difference by implementing the dependent sample t-test.

In the qualitative phase, a collaborative research was employed. According to Silverman (2000), a collaborative study is a kind of qualitative research done in collaboration with practitioners with the principal aim of generating knowledge and understanding of practice. Hatch (2002) argues that collaborative qualitative research brings in both participants and researcher perspectives to the analysis of the phenomena under investigation. In this study, the participants' perspectives were incorporated into the research largely in the form of participation in workshops, post-teaching discussions as well as interviews.

Under the collaborative research, the case study method was followed. According to Hitchcock and Hughes (1989), case study is the in-depth study of a case or a situation. This method allows for the investigation of one or a few cases in order to gain an understanding of one phenomenon in depth within a limited context.

Case studies can be exploratory, when conducted prior to the formulation of research questions usually as a prelude to other research; explanatory if aimed at causality; or descriptive if the research begins with a descriptive theory and aims to hypothesise about cause-effect relationships (Freebody, 2003; Silverman, 2000). This study was interpretive in nature in that the researcher seeks meanings and relationships between theoretical and contextual conditions. Hence, data was collected at the end of a six weeks period of interaction and observation of the practices of the five science teachers and their Grade 11 learners, thus providing the researcher with thick data on classroom interaction in their specific contexts. Data collection techniques selected was used to extract data on what teachers did and how they did it (direct classroom observations) as well as why they did it (interviews). Although the findings from case studies cannot be generalised but can provide insights into aspects of the big picture of (in this case) the possible use of learning style-based instructions as a strategy for implementation of the new science curriculum at FET level to improve learner performance in the subject in South Africa.

3.4 Sampling and sampling methods

Target Population

The target population was drawn from five high schools around Mthatha. The population consisted of 245 registered grade 11 physical science learners and five physical science teachers who collaborated with the researcher at the research sites. The study was conducted in July-August, 2017. The entire class of each school with their science teacher were invited to participate in the study.

Sampling method

Mujere (2016) defined sampling as the procedure or method of selecting an appropriate sample to represent part of a population for the purpose of determining characteristics of the whole population. According to Singh (2013), sampling is the process of selecting units from a population of interest so that, by studying the sample, one can fairly generalise the results

back to the population from which they were chosen. Sampling population units, such as students in a high school enrolled to study a particular subject, cases (e.g., schools) and pieces of data **(**e.g., university applications in a country).

Two main types of sampling techniques are mostly employed in research (McMillan & Schumacher, 2010, p.129-138): probability sampling techniques and non-probability sampling techniques. In probability sampling, each sample has an equal probability of being chosen. A probability sample is one in which each element of the population has a known non-zero probability of selection. Unlike the probability sampling method, non-probability sampling techniques use non-randomised methods to draw the sample. Non-probability sampling method mostly involves judgment. Alvi (2016) explains that, instead of randomisation, participants are selected because they are easy to access.

The sample technique which was used in this study to select the five schools, learners and teachers was convenient and purposeful. Convenience sampling, according to Leedy and Ormrod (2013), selects people or other units which are available and easy to access. According to Opie (2004) and Freebody (2003), purposive sampling is the deliberate selection of respondents for a particular reason or to represent a specific population In purposive sampling, the researcher chooses the participants as per his/her own judgment, keeping in mind the purpose of the study (Alvi, 2016). In this study, purposeful and convenience sampling were used to identify research sites and research participants. Five schools (n=5) located in and around Mthatha Municipality, in the Eastern Cape Province of South Africa, were purposively and conveniently sampled from a total of 23 high schools in the municipality. All five schools are public schools with one of them being a former model C school. Former model C schools have good facilities, the best teachers and the best educational opportunities for learners. However, the four other schools sampled for this study also had the necessary facilities for science teaching and learning.

For this study, the selected schools can be described as generally uniform in terms of availability of teaching and learning resources for physical science and in class sizes. Each of the selected schools has at least one science laboratory for use in physical science teaching. The average class size for grade 11 at each of the schools was approximately 52, with the exception of the former model C school which had a class size of 38. Each of the grade 11 classes at the selected schools was taught by a qualified science teacher, implying that the

selected schools were functional schools. The five schools were easily accessible and conveniently located within the same cluster the researcher works. One school was randomly assigned to the control group and the four other schools were randomly assigned into the experimental group. The random assignment of schools into experimental and control groups was necessary in order to show the effect of an intervention, as well as associations and trends. This was done before the commencement of the study.

Participants in the study

The sample comprised five physical sciences teachers and 245 physical science learners. Each teacher participated in the project with one of his/her classes. Sampling therefore, in the case of the selection of teachers and their classes, was context and time bound. The researcher sought to understand how learning-style-based instructions played out in the classrooms where it was actually practiced and so the selection was biased towards teachers who showed evidence of willingness to use this instructional strategy in their classrooms. Thus, participation in the study was both voluntary (based on the teachers and learners' willingness to participate in the study) and purposive in that only those teachers who showed consistent commitment to use the learning style-based instructions as a teaching strategy in their classrooms were approached.

Each sampled school randomly selected one intact grade 11 class for the study, giving a total of 245 learners. The average class size for grade 11 at the five schools was approximately 52, and that of the former model C school was 38. All the 245 learners completed the index of learning style questionnaires at the beginning of the study. In addition, all the 245 learners also participated in the quantitative part of the study, were involved in the class observations and completed the PSAT questionnaires.

For the qualitative part of this study, participants were selected from samples in the quantitative phase of the study. In sequential mixed method design, as Teddlie and Yu (2007) assert, the methodology and results of the first phase informs the methodology employed in the second phase. This is because the final sample in the first strand of the study can be a sample frame for the second strand (Teddlie & Yu, 2007). Four learners from each sampled school who had also completed the other research instruments were purposefully sampled (ensuring gender balance) to take part in the semi-structured interviews, giving a total of 16 learners (eight boys and eight girls) as Freebody (2003) argues that, in qualitative research

studies, samples are small and may be difficult to constitute because the researcher is seeking in-depth understanding of a phenomenon.

The 16 learners were selected based on (a) their consent to participate; (b) their extremely high or low performances on the PSAT test with the same learning style; (c) their extremely high or low achievement on the PSAT test but with different learning style combinations. The extreme performances of the learners were identified from the descriptive statistics in the quantitative study. The average age of the learners was 17 years (age range 16 to 18 years).

In addition, all sampled learners were selected from English medium schools since the two compulsory official South African languages offered to the learners were English or IsiXhosa (as first language) and English, IsiXhosa or Afrikaans (as second additional language). In addition to physical sciences, Life Orientation and languages, all the learners offer at least three elected subjects.

This study purposefully sampled one teacher (ensuring gender balance) each from the five sampled schools, giving a total of five teachers (three males and two females). The five teachers were then pseudo-named as Mrs George, Mrs Anane, Mr Mvana, Mr Thobela and Mr Billie. These teachers were selected for the study because they were keen to try out the learning style questionnaire and the learning style-based instructional strategies in their respective classrooms because they had not had the opportunity to explore the phenomenon earlier in the workshop. In addition, these teachers willingly agreed to re-sequence their pacesetter content to teach electricity and magnetism in grade 11 in the first few weeks in term three of 2017 during the period of the study.

Teachers' profile

In this investigation, every effort was made to avoid putting the participants in the study at risk and to guarantee that all participants were respected and protected in order to ensure that the information from the study would not be used against them. Pseudonyms are also used so that they are not identified.

Mrs Anane is a physical science teacher who has taught the subject for the past 22 years, both abroad and in South Africa. She holds a teacher's diploma and a Bachelor and Honours degree in science from a university in Ghana. She has a very good grasp of science and she is diligent in making topic preparations ahead of her lessons by reading and researching the

topics that she was to teach. She is the Head of Department (HoD) of science and mathematics and also a member of the school management team (SMT). As a result, she does a lot of administrative work in the school, monitors teachers' lessons, moderates the work of other teachers and also does the entry of grade 12 learners for NCS examinations. Because of these other responsibilities, she is allocated two classes for physical science, one grade 12 and one grade 11.

Mr Thobela is a physical science and mathematics teacher who has been teaching at this urban school for 10 years. Mr Thobela's highest qualification is an Honours degree in Science Education, following a four-year Bachelor's degree in Science and Mathematics Education. He is passionate about the work he does and teaches grades 10, 11 and 12 physical sciences as well as one grade 10 classes for mathematics.

Mr Mvana has 12 years teaching experience, 10 of which he taught physical sciences and life sciences. He is a post level 1 teacher who holds a Bachelor's degree in physical science (as a major) with a minor in life sciences and an Honours degree in physical science. He teaches two grade 12 classes and one grade 11 class. In addition, he teaches natural sciences in one grade 9 class. Mr Mvana is the school's sport master; he is also responsible for the school's time table planning and is in charge of examinations.

Mrs George has a Bachelor of Science degree and a Post-Graduate Certificate in Education degree from the Walter Sisulu University of Science and Technology. She has been teaching physical sciences in her school for the past 20 years. In 2008, she was appointed as the Head of Department (HoD) for science and mathematics in her school. She is an active member of the school's SMT and does a lot of moderation work for her department. She often facilitates workshops organised by the subject advisor for science teachers in the district. She teaches three grade 11 classes for physical sciences.

Mr Billie has 10 years teaching experience, nine years of which he taught physical sciences and mathematics. He is a post level 1 teacher who holds a Bachelor's degree in biochemistry and a Postgraduate Certificate in Education in Physical science. He teaches two classes for grade 12 and one class for grade 11. In addition, he teaches mathematics for one grade 9 class.

The five science teachers sampled for the study have high school teaching experience ranging

from 10s to 25 years and have regularly attended content gap and in-service training to upgrade their knowledge in the subjects that they teach. All sampled teachers were teaching physical science at Further Education and Training (FET) level, that is, grades 10, 11 and 12 and either mathematics or natural science at General Education and Training (GET) level, that is, grades 8 and 9.

Table 3.2: Teacher demographic variables

TEACHER'S CODE	PSEUDONYM	GENDER	TEACHING EXPERIENCE	QUALIFICATION	SCHOOL TYPE
STI	Mrs. Anane	Female	22 years	Diploma in Education, B.ED(Sciences), Hons. B.ED (Sciences)	Former Model C
ST2	Mr. Mvana	Male	12 years	Hons. B.ED (Physical sciences & Life Sciences)	Public
ST3	Mr. Thobela	Male	10 years	Hons. B.ED (Maths & Physical Sciences).	Public
ST4	Mrs. George	Female	20 years	BSC. (Physics), PGCE (Physical Sciences).	Public
ST5	Mr. Billie	Male	10 years	BSC. (Biochemistry), PGCE (Physical Sciences).	Public

3.5 Research instruments: Development, validation and reliability

According to Pierce (2009), a data collection instrument refers to a survey, test tool, evaluation tool, or assessment tool designed to measure the variables, characteristics or elements of research interest. In the quantitative phase of this study, Felder-Silverman's Index of Learning Styles Questionnaire (ILSQ) and a Physical Sciences Achievement Test (PSAT) questions (pre-test and post-test) were used as the main instruments to collect data. In the qualitative phase of the study, classroom observations and semi-structured interviews for learners and teachers were used to gather data. In the sections that follow, the instruments used to gather data, their validation and reliability are discussed.

3.5.1 Felder-Silverman Index of Learning Style Questionnaire (FSILSQ)

The Felder-Silverman Index of Learning Style Questionnaire (FSILSQ) instrument (see Appendix A1) was adopted and modified with permission from the authors. However, minor

syntactical changes were made to the FSILSQ instrument for consistency purposes. The table below illustrates the changes made to the original version of the FSILSQ.

Table 3.3: changes made to the statements in the FSILSQ learning styles questionnaire

Original statements	Changed statements
I would rather be considered realistic.	I would rather be considered as someone who has a good grip on the reality of a situation.
I would rather be considered innovative.	I would rather be considered as creative.
If I were a teacher, I would rather teach a course.	If I were a teacher, I would rather teach a subject.
I prefer the idea of certainty.	I prefer the idea of true fact.
When I see a diagram or sketch in class, I am most likely to remember what the instructor said about it.	When I see a diagram or sketch in class, I am most likely to remember what the teacher said about it.

The FSILSQ was specifically chosen against competing alternatives for this study for the following reasons:

- It has been explicitly developed for classroom application and, though suitable to profile individual learning preferences, as argued by Felder (1988), the results provided a better indication of the preference of a group of learners.

- The model was purposefully developed to improve achievement in engineering and hence can be applied in other fields of science, for example, physical sciences because of its comprehensiveness (Mihrka & Schulze, 2016).

- The model has been successfully implemented in previous works and its validity and reliability have been justified (Litzinger, Halee, Wise, & Felder, 2007).

- The model is popular in the academic world since it represents elements from other models (Yousef, 2016).

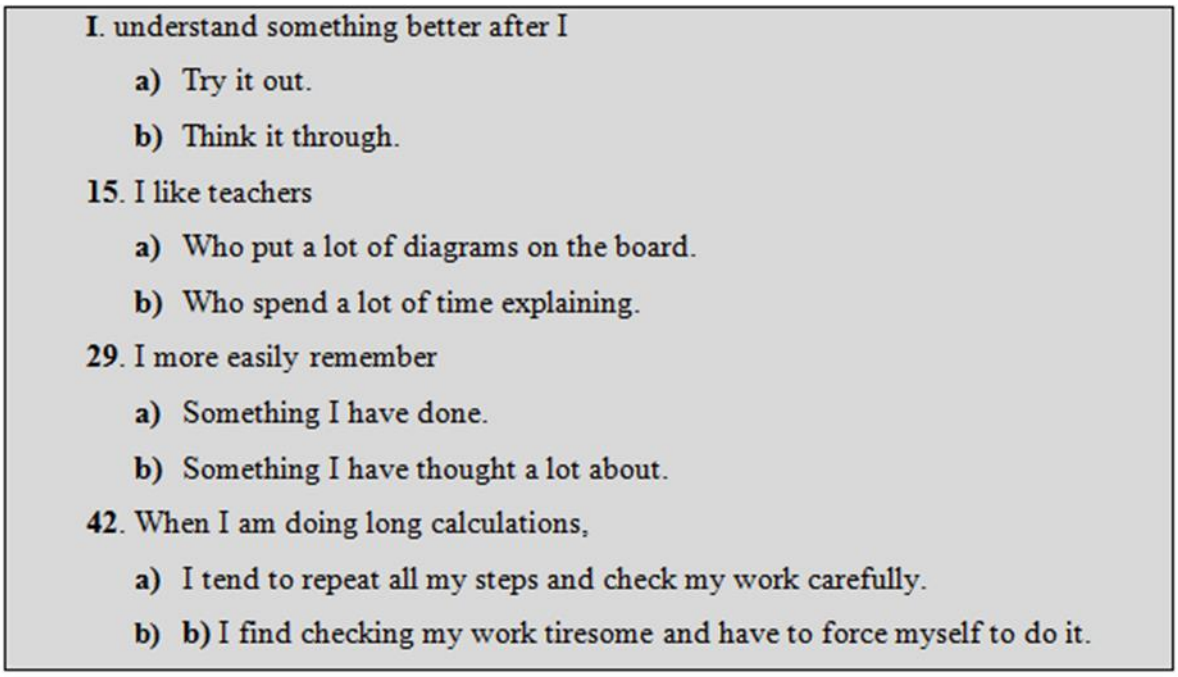
- It is user friendly and the results are very easy to interpret.

- The number of dimensions on the questionnaire can be controlled and can actually be implemented (Paredes & Rodriguez, 2002).

- The data obtained by the instrument is comparatively easy to analyse and is suited to statistical analysis.

Although this study employed Felder-Silverman's learning style questionnaire, it kept the relative construct validity of the dimensions in mind when analysing the results and since the study was conducted in South Africa, some of the terms used were changed to suit the study context. However, the scales used were based on those of the original authors of the questionnaires.

The Index of Learning Styles (ILS), developed by Felder and Silverman (1988), is a 44-item questionnaire for identifying the learning styles according to the Felder-Silverman Learning Style Model. An extract from the FSILSQ instrument is shown in Figure 3.2 below:


I. understand something better after I

a) Try it out.

b) Think it through.

15. I like teachers

a) Who put a lot of diagrams on the board.

b) Who spend a lot of time explaining.

29. I more easily remember

a) Something I have done.

b) Something I have thought a lot about.

42. When I am doing long calculations,

a) I tend to repeat all my steps and check my work carefully.

b) b) I find checking my work tiresome and have to force myself to do it.

Figure 3.2: An extract from the FSILSQ instrument showing examples of items on the questionnaire

Every learner has a particular inclination towards each LS dimension. These preferences are articulated with values ranging from +11 to -11 per each LS dimension. This range originates from the 11 questions that are posed for each LS dimension. For instance, when answering a question with an active preference, plus 1 is added to the value of the active dimension while 1 is subtracted from an answer for a reflective LS preference. Therefore, each question is answered either with a value of +1 for *a* or -1 for *b*. An answer "*a"* corresponds to the

preference for the first pole of each dimension (active, sensing, visual or sequential) and answer "*b"* to the second pole of each dimension (reflective, intuitive, verbal, or global). The questionnaire request respondent to select one of two endings to a sentence that emphases on some characteristics of learning. Recording is 1, 3, 5, 7, 9 and 11, with 1 and 3 indicating a balance along the scale and 7 showing a moderate preference for one end of the scale, 9 and 11 indicating a strong preference for one end on the other.

Minor morphological modifications were made on the FSILSQ instrument. For instance, in the ILQ questionnaire, the term "course" was replaced by "subject" and the term "student" was replaced by "learner" in the FSILSQ. This was done for consistency purposes. The thesis focuses on learners and not students and, as such, it was felt that wording had to be changed to agree with the focus of the thesis.

To validate the FSILSQ instrument, a version was pilot tested with 40 grade 11 learners from one class at a high School purposively and conveniently sampled in Mthatha. After completing the instrument, five learners were again purposively selected based on their responses to the FSILSQ. These learners were selected because the researcher wanted to check on learners' understandings of the complexity of the English language level used in the questionnaire due to the fact that the learners who formed the population of the study were predominantly Xhosa speakers and English serves as a second language and as the medium of instructions in these schools. Firstly, they were interviewed individually and later as a group about whether they had difficulties understanding the complexity of the language in the questionnaire. The learners were also asked to comment on what they thought the instrument was designed to measure. It emerged from this that the learners understood that the questionnaire sought to elicit their views on what their preferences were in terms of how they receive and process information during teaching and learning processes. The science teacher for the class was also asked to comment on the questionnaire.

Face validity, content validity and construct were further evaluated by a panel of five experts (one professor, two doctors who included the supervisor of this study and two doctoral candidates) from different universities. These experts were asked to comment on its face value and the relevance of the content and constructs included in the questionnaire. All the experts who were asked to face validate the instrument approved it.

Table 3.4: An extract from the FSILSQ instrument with options

Items	Concepts	A	B
1	I understand something better after I…?	Try it out	Think it through
2	I would rather be considered……?	Realistic	Innovative
3	When I think about what I did yesterday, I am most likely to get….?	Picture	Words
4	I tend to……?	Understand details of a subject but may be fuzzy about its overall structure.	Understand the overall structure but may be fuzzy about details.
5	When I am learning something new, it helps me to….?	Talk about it	Think about it

3.5.2 The design of the Physical Sciences Achievement Test (PSAT)

The PSAT was designed by the researcher and was used to collect data from the learners to understand the effectiveness of the learning style-based instructional strategies (Appendix E). The researcher developed the PSAT on the topics of electricity and magnetism. This was administered to the learners both pre-test and post-test. The test consisted of multiple choice questions; each question carried two marks. According to Burton, Sudweeks and Merrill (1991), a multiple choice test is an appropriate instrument to measure different educational objectives, as it is easy and efficient to administer. The details regarding the construction of the PSAT are given below:

- Deciding on the instructional objectives of the test;
- Content analysis;
- Preparing the blue print;
- Preparation of the draft;
- Standardisation of the test;
- Try testing of the test.

Deciding on the instructional objectives of the test

All aspects of instruction were based on certain aims or objectives that would result in learning which, in turn, could bring about changes in the behaviour of learners. Instructional objectives are the anticipated behavioural changes of learners, expected by teachers as a result of their teaching. In the present study, the instructional objectives of teaching science according to the specific aims of physical sciences (see section 1.1) were followed.

According to the CAPS document, assessment tasks should be done at all cognitive levels in all knowledge areas and on all scientific tasks. Assessment Taxonomy, according to CAPS, is described in detail in the table below:

Table 3.5: Physical sciences assessment taxonomy

Level	Explanation	Skills demonstrated	Action verb
1	The learner is able to recall, remember and restate facts and other learned information	Recognising; naming; listing; describing,; retrieving; recalling; identifying	List, define, tell, describe, identify, show, know, label, collect, select, reproduce, match, recognise, examine, quote, name.
2	The learner grasps the meaning of information by interpreting and translating what has been learned.	Interpreting; exemplifying; comparing; explaining; inferring; classifying	Summarise, describe, explain, give main idea, contrast, associate, distinguish, estimate, differentiate, discuss, extend, comprehend.
3	The learner appreciates the significance of the parts in relation to the whole of the content. Elements embedded in a whole are identified and the relations among the elements are recognised. The learner has the ability to apply knowledge and skills in other familiar situations.	Organising; comparing; deconstructing; attributing; outlining; finding; structuring; integrating.	Analyse, separate, order, connect, classify, arrange, divide, compare, select, infer, break down, contrast, distinguish, draw, illustrate, identify, outline, point out, relate, question, appraise, argue, defend, apply, debate, criticise, probe, examine
4	The learner creates new ideas and information using the knowledge previously learned or at hand. At the extended abstract level, the learner makes connections not only within the given subject area but also beyond it.	Generating, planning, producing, designing, Inventing, devising, making, monitoring, detecting, judging, hypothesis, experimenting	Devise, predict, invent, propose, construct, generate, make, develop, formulate, improve, plan, design, produce, forecast, compile, originate, imagine

Content analysis

For the researcher to give due weightage to each section of the selected topics, each section

was sub-divided into sub-sections. The analysis of the sub-sections is given in Tables 3.6 to 3.8 below.

Table 3.6: Content analysis of section 1: Electrostatics

No	Content Analysis
1	Coulombs law: -Use of Coulombs in problem solving.
2	Electric field: electric field lines , magnitude of electric field lines,
3	Electric field strength.
4	Force acting on a charge in an electric field lines.

Table 3.7: Content analysis of section 2: Electromagnetism

No	Content Analysis
1	Magnetic effect of a current-carrying conductor.
2	Magnetic field around a magnetic
3	magnetic field around a solenoid
4	Environmental impact of overhead electric cables.
5	Faraday's law
6	Current induced by a changing magnetic field.
7	Magnetic flux
8	induced emf and an induced current

Table 3.8: Content analysis of section 3: Electric circuit

No	Content Analysis
1	Ohm's law
2	The relationship between current, voltage and resistance.
3	Solving circuit problem
4	Power and energy
5	Electric power and dissipation in a device
6	Solving circuit problem involving power
7	The cost of electricity usage.

Preparing the blue print

PSAT was developed with proper weightage of marks to ensure tasks provided opportunities for learners to achieve at various cognitive levels. The blue print of the test is given in Table 3.9 below.

Table 3.9: Blue print of the physical sciences achievement test

Paper	Content	Marks	Number of Questions	Weighting of Questions across cognitive levels				
				Level 1	Level 2	Level 3	Level 4	Total %
1	Electricity and Magnetism	50	14	15%	35%	40%	10%	100%
	The break down							
	Sub-section: Electrostatics	16	16	2	6	7	1	32%
	Sub-section: Electromagnetism	16	16	2	6	7	1	32%
	Sub-section: Electric circuit	18	18	4	5	6	3	36%
	Total	50	50	8	17	20	5	100%

Table 3.9 reveals that the weighting for electricity and magnetism, according to the CAPS document, is 50 marks in total. This mark is broken down according to the sub-sections under electricity and magnetism. The total number of items in the test was 50 multiple choice items, each carrying two marks, making a total of 100 marks. Test items cover the four cognitive levels; eight items for recall; 17 items of comprehension; 20 items of analysis and application and five items of evaluation and synthesis. The test items were allocated one hour for completion for both slow and fast learners.

Preparation of the draft

With the support and help of experts and experienced teachers in the field, the researcher was able to prepare the Achievement Test with multiple choice items from the entire three sections under the topic "electricity and magnetism". The draft test contained 50 items. Necessary instructions for taking the test were given on the first page of the document. Due weightage was given to the objectives, content and difficulty level, and discrimination value of the test item.

Each question had four optional responses and they were marked as A, B, C, and D. Response sheets were also prepared for the draft test. The respondents had to mark the box corresponding to the correct alternative of each item with an "X". The researcher also prepared the memorandum for the test items in the draft test. The draft test, response sheets and the memorandum are given in Appendices E1, E2, and E3.

Weightage to difficulty level

The test items contained easy, average and difficult questions to cater for the differences among learners in the science classroom. The weightage given to different difficulty levels are presented in Table 3.10 below.

Table 3.10: Weightage to difficulty level

No	Difficulty level	Marks	Percentage
1.	Easy	12	24
2.	Average	26	52
3.	Difficulty	12	24
Total		50	100

Expert opinion on the test

After editing the PSAT with 60 items, the test was given to experts (a subject advisor for physical science, Doctor of physics, PhD scholar in science and a physical science teacher) who were asked for their opinion regarding the test and requested to check the achievement test considering the following points:

a) Are the items suitable according to the content and methodology?

b) Does each item have proper distracters?

c) Does the science achievement test have proper Difficulty value and Discrimination value?

d) Is the Science Achievement Test properly structured?

e) Are the stems of the items properly constructed according to the level of learners?

The experts were requested to make suggestions and comments, if they had any, relating to the above questions. A copy of PSAT given to experts is given in Appendix E1. Comments and suggestions from experts resulted in the removal of ten items from the test. Thus 50 questions were included in the pilot form of the science achievement test.

Pilot testing of the preliminary form of the PSAT test

The test items were pilot tested for item analysis and also to decide on the time limit for the final form of the achievement test. In addition, it was necessary to pilot test the test items to decide on the discrimination ability of the test and also to decide on the difficulty level of the

test as learners responded to the test items.

The pilot test was done on 40 grade 11 learners from a school in the same cluster as the sampled schools. According to Wellington and Szczerbinski (2007), piloting is a vital part of questionnaire design and construction. Therefore, pilot testing was employed in this study to improve reliability (Leman, 2010; Babbie, 2010), and further to test for validity. In addition, piloting this research instrument tested for the layout, language use and possible ambiguity, clarity of instructions, acceptability of the statements and the length of the questions (Babbie, 2010).

The school chosen for pilot testing shares similar characteristics with the sampled schools. The researcher personally administered the questions. The learners were informed that this was a pilot test of the questions and that all responses were to remain anonymous. The scoring was done according to the memorandum prepared (see Appendix E2).

The following modifications were made to the questions after receiving feedback from the learners:

- Time allocation was adjusted to 60 minutes.
- Question 23 was found to be too vague and ambiguous to the learners.
- Questions 31 and 42 were found to be very similar.
- Question 46 was unclear to the learners, hence it was modified.

Item Analysis

According to Quaigrain and Arhin (2017), item analysis is the process of establishing the suitability of an item for inclusion in the final test. A quantitative analysis of the items was done in terms of the statistical properties mainly using the measurement of item difficulty (difficulty index) and item discrimination (discriminating power).

Difficulty Index (p)

According to Sim and Rasiah (2006), the item difficulty index (P) refers to the percentage of the total number of correct responses to the test item. Thorndike, Cunningham, Thorndike and Hagen (1991) state that an item difficulty index indicates the percentage of respondents who answered an item correctly therefore it is calculated as a percentage of the total number of

accurate responses to the test items. Item difficulty index is calculated so that only items with suitable difficulty indices were included in the test. It is done using the formula $p = \frac{R}{T}$ where p is the item difficulty index, R is the number of correct responses, and T is the total number of responses.

The higher this index value, the lower is the difficulty and the greater the difficulty of an item, the lower is its index. The higher the *p* value, the easier the item which implies the higher the difficulty index, and the easier the item is assumed to be. Test items with a *p*-value ranging from 20% to 90% are regarded as worthy and suitable. Test items with *p*-value ranging from 40 to 60% are regarded as exceptional, since DI is extreme at this range. Test items with *p*-value lower than 20% (too difficult) and more than 90% (too easy) are unacceptable and need to be revised. The commended range of item difficulty is from 30 to 70%. Test Items with p-values below 30% and above 70% are regarded as difficult and easy items respectively as recommended by Miller, Linn and Gronlund (2009). Very easy items should generally be placed at the beginning of the test or removed completely. The difficult items should be revised for possible ambiguity, language difficulty, areas of disagreement, or even an inappropriate wording.

According to Hingorjo and Jaleel (2012), adding challenging items in the test depends solely on the objective of the teacher, who may want inclusion for the purpose of assessing the extent of impact of his/her instructions. The optimum *p* value for an item depends on a number of factors, including the purposes of the test and the number of response options. However, there is a need to conceptualise that a *p*-value is basically a behavioural measure. As an alternative to explain difficulty in terms of some inherent elements of the test item, Thorndike et al. (1991) suggest the use of relative frequencies with which those taking the test choose the correct response. Table 3.10 shows the frequency distribution of difficult index of the test items.

Table 3.11: Frequency of difficulty indices

Difficulty Indices	Frequency	Percentage
0 - 9	1	2
10 - 19	1	2
20 - 29	5	10
30 - 39	3	6
40 - 49	5	10
50 - 59	6	12
60 - 69	10	20
70 - 79	12	24
80 - 89	4	8
90 - 99	3	6
Total	50	100

Table 3.11 shows that the majority of the items, 48 (96%), were of acceptable levels of difficulty with a p-value within a range of 20 to 90%, while 21 (42%) items among them had excellent p-values with a range of 40 to 60%. Two items (4%) were identified to be too difficult with a p- value of less than 20%.

Discriminating Power (D)

The discriminating power (D) is a measure of the effectiveness of an item in discriminating between high and low scores on a test. The greater the score of the discriminating power, the more effective the test item is in discerning between items with high scores and items with low scores on the test in general. When D is 1.00, all the examinees in the upper group and none of those in the lower group on total test scores answered the item correctly. An item is usually considered acceptable if it has a D index of 0.30 or higher. However, Aiken (2003) points out that D and *p* are not independent indices, and the minimum acceptable value of D varies with the value of *p*.

Based on Ebel's (1972) guidelines on classical test theory item analysis, items were categorised in their discriminating indices as follows:

(1) If the discriminating index (DI) is greater or equal to 0.40($D \geq 0.40$), the test item is operationally satisfactory.

(2) If the discriminating index (DI) is less than or equal to or greater than 0.39 ($0.30 \leq DI \leq 0.39$), then the test item is satisfactory. No revision is required.

(3) If the discriminating index (DI) is less than or equal to 0.29 ($0.20 \leq DI \leq 0.29$), then the item is minimal and needs to be revised.

(4) If the discriminating index (DI) is less than or equal to 0.19, ($DI \leq 0.19$), then the item should be eliminated or completely revised

Table 3.12: Distribution of discrimination indices

Discrimination indices	Frequency	Percentage
<0	4	8
0.1 - 0.19	5	10
0.2 - 0.29	5	10
0.30 - 0.39	20	40
0.40 - 0.49	16	32
Total	50	100

From the analysis of distribution of DI from Table 3.12, the test item with the greatest DI was item 0.30 – 0.39 and the item with the lowest DI was item <0. Thirty-six of the items (72%) have very good to excellent discrimination indices ($DI \geq 0.30$). Accordingly, 14 items (28%) have very low discriminating power and should be revised.

In all, 96% of the items were of acceptable level of difficulty and 72% were excellent discrimination indices. That led to the revision of the few items that had both low difficulty index and low discrimination power

Selection of items for the final test

Items having difficulty index within the range of 20% to 90% and discriminating power of 0.30 and above were taken for the final test. Thus 50 items were selected for the final test after revision.

The item difficulty indices were used to rank the items from the easiest to the most difficult in the final test. Nunnally and Wilson (1975) suggest that placing easier items in the beginning provide respondents with an optimistic start and placing more difficult items near the end prevents respondents from spending too much time on items early in the testing period. The final form of the PSAT is given in Appendix E1.

Response Sheets and Answer Key

The researcher prepared the response sheets and answer key of the items in the final test. The test was scored according to the response key indicated with the letters A, B, C and D. The response sheet and answer key are given in Appendix E2.

Final form of the test

After incorporating suggestions on the physical science achievement test from experts and the piloting of a preliminary form of the achievement test, a final form was obtained. The final form had the instructional page and test item pages. The instructional page gave instructions to learners and introduced the achievement test. It also gave information regarding how the respondents should answer the questions on the answer sheet.

The PSAT contained 50 test items. Each item consisted of a stem and four alternatives from which respondents made a choice. There was only one correct answer from the four alternatives. The final form of the test had 50 marks (converted into a percentage) and the time limit was 60 minutes. A duplicate of the Science Achievement Test is presented in Appendix E1.

Reliability of the Achievement Test

Reliability of the test was established by test-retest method on a sample of 40 learners from a school purposefully and conveniently sampled that did not form part of the main study. The test-retest was administered after an interval of four weeks. The association between the first set of scores and the second set of scores was determined. The reliability coefficient obtained was 0.79.

Validity of the achievement test

Before the construction of the test, a thorough analysis of the curriculum objectives was done with the help of the CAPS documents. The test was constructed keeping in mind the weightage given for content area with instructional objectives related to the topic. Test items were then checked by the subject experts to see whether they corresponded to what the researcher intended to be covered by the test. Thus, content validity of the test was established.

3.5.3 Learner semi-structured interviews

Darlington and Scott (2002) posit that interviews are the most commonly used method for collecting qualitative data mainly because interviews allow the researcher to have a deeper understanding of the phenomena at hand, from the respondents. Semi-structured interviews were selected as the means of data collection for the qualitative part of this study for the following reasons: firstly, semi-structured interviews were well suited to the exploration of the perceptions, conceptions and opinions of respondents regarding the impact of learning style-based instructions on learner achievements. Secondly, the researcher wanted to induce first-hand information from learners with regard to their perspectives on how culture can influence learners' learning styles.

A total of 16 learners were selected for the interviews. Silverman (2000) maintains that a semi-structured interview involves a set of open-ended questions that allow for spontaneous and in-depth responses. The interviewer followed standard questions but added one or more individually tailored questions to seek clarification or probe a person's reasoning as recommended by Leedy and Ormrod (2013). Such a method of data collection is very useful in exploratory types of research (Sahu, 2013) as it allowed the researcher to get more detailed information in a flexible manner and avoid misinterpretation.

To validate the interview questions, a total of five learners were purposively selected based on their responses to the FSILSQ and the PSAT instruments which they had completed earlier during the pilot test. The researcher interviewed the five respondents based on their answers and their understanding and interpretation of the questions used during the pilot study. Feedback from the learners enabled the researcher to revise the questions which appeared to have given learners problems of understanding and interpretation.

The remaining 10 questions elicited learners' views on selected aspects of the following broad issues: learning style preferences, learning style-based instructions and cultural attributes on learning styles in science.

3.5.4 Teacher semi-structured interviews

Four physical science teachers were interviewed for the purposes of corroborating responses and to get a deeper understanding of teachers' perceptions and conceptions of learning style-

based instructions and their impact on learner achievement, and also to get a deeper understanding of the role of cultural influence on learning style preferences. In order to get this information, each teacher was asked a set of core questions around which probing for clarification and deeper understanding was done.

The teachers' interview questions were constructed after the literature review. The instrument was validated by experts: one university professor, my supervisor, one doctoral candidate and one master's student, all working in the field of teacher development, were given the instrument to validate.

A readability concern for the instrument was addressed by this validation process. According to Richardson (2008), the extent of reliability and trustworthiness of any interview can be measured on the cooperativeness, consistency and confidence of participants' responses to the questions asked.

3.5.5 Class Observation Schedule

The final instrument for collecting data was done through the use of a non-participatory classroom observation tool to observe five (n=5) physical sciences teachers' class sections for the purpose of triangulating information from the learners' and teachers' interviews and the PSAT. In addition, classrooms were observed to describe in detail the teachers' use of learning style-based instructions that supported learners' learning style preferences and learners' cultural backgrounds. According to Cohen, Manion and Morrison (2007), a semi-structured, non-participatory observation of classroom sections are done to capture as much information as possible of the classroom events as well as to determine the nature of the instructions. Three lessons were observed by the researcher in each of the five participating teachers' classrooms, making a total of 15 lesson observations for the purpose of learning about teachers' general classroom practices in the implementation of learning style-based instructions and learners' classroom engagement in the instructional processes. In addition, classes were observed to describe teachers' different teaching strategies that supported learners' learning styles in detail, specifically with regards to the ways that the teachers identified, interpreted, evaluated and responded to their learners' learning styles instructional needs. This was done to ensure that teachers were on par in terms of the implementation of the instructional strategies in their classrooms.

Classroom observation is a commonly used method of training and evaluation in the five sampled schools because pre-service teachers from Walter Sisulu University (WSU) have their class observations and teaching practices in these schools. As such, it did not cause any disruptions or changes to any classroom.

The researcher performed the non-participatory classroom observations using the Center for Community College Student Engagement (CCSSE) (n.d.) classroom observation tool, a project of the University of Texas at Austin. According to Gore (2015), the CCSSE classroom observation tool is a component of the CCSSE evaluation process, the validity and reliability of which has been established through extensive testing. A study conducted by Mandarino and Mattern (2010) for the Higher Education Quality Council of Ontario, Canada, tested five constructs, enumerated in the Model of Effective Educational Practices (MEEP), against the results obtained by administration of the CCSSE at a large technical college in Ontario. The study found that the CCSSE results mapped well into the five MEEP constructs: active and collaborative learning, student effort, academic challenge, student-faculty interaction and support for learners. Mandarino and Mattern (2010) report consistency between the MEEP constructs and the underlying constructs measured by CCSSE in their sample at statistically significant levels ranging from Cronbach's alphas of 0.38 for student effort to 0.75 for academic challenge. They also found a correlation between those constructs and positive student outcomes.

Reliability of the CCSSE has been established through the length of time that it has been in use, the number of assessments that have been performed and a method of benchmarking that involves intra-year comparison by always using a three year sliding window of data. In other words, as described in a paper produced by the Barstow Community College (2011), CCSSE data analysis is based on a three-year cohort at participating colleges, for instance, the 2011 CCSSE cohort refers to data from 2009 through 2011. The paper reports that the current method of CCSSE benchmarking and analysis has been in use since 2006 and that, in 2011, the CCSSE was administered at 699 educational institutions to a cohort totalling 443,818 students. The CCSSE observation tool (see Appendix B1) calls for an observer to record a number of classroom observations using a Likert-type scale supplemented by a comment section for each observation. Two of the constructs that the CCSSE tool is designed to measure are teaching style and instructional techniques. The instrument also calls for an observer to report the level of engagement of students in the observed classroom.

The CCSSE was adapted as an analytical tool for the analysis of teachers' practices of learning style-based instructional strategies in physical sciences classrooms. Specific permission for the use of the CCSSE observation tool was obtained from the University of Texas at Austin (see Appendix B2).

The observation tool is divided into six sections:

- Section A: Learning Organisation and Management;
- Section B: Knowledge of Subject Matter;
- Section C: Teaching Style;
- Section D: Instructional Techniques;
- Section E: Encouragement to Engage in Critical Thinking; and
- Section F: The overall score.

Sections A through E are sub-divided into several specific sub-sections. The capture of lesson proceedings was guided by a deliberate effort to examine those sub-sections. The rating scales are: Completely, Adequately, Minimally, Not at all, and Not applicable. The section D has percentages equated to: Completely: 75% - 100%; Adequately: 40 - 74%; Minimally: 20 - 39%, Not at all: 1 - 19%; Not applicable: 0%.

For each of the observed lessons, proceedings were video-recorded (with permission from the sampled teachers) from the back of the classroom as the researcher sat at the back and took detailed notes of the lesson.

In the section that follows, specific quality criteria applicable to the respective research designs were considered for the development of the data collection instruments, since the study envisaged yielding conclusive results. Issues around validity and reliability relevant for the study are raised and discussed. In any research study, it is necessary to maintain acceptable standards. Therefore, an overview of validity and reliability for the mixed method approach employed in this study is given and discussed below.

3.6 Quality criteria

3.6.1 Quality criteria applicable to the quantitative research design

The researcher focused on reliability by obtaining "consistency and stability of a set of test scores" (Johnson & Christensen, 2008) and on validity to ensure that the research is representative of what the researcher is investigating (Welman, Kruger, & Mitchell, 2005).

Reliability

Joppe (2000) defines reliability as:

> "The extent to which results are consistent over time and an accurate representation of the total population under study is referred to as reliability and if the results of a study can be reproduced under a similar methodology, then the research instrument is considered to be reliable" (p. 1).

This implies that uniform conditions for collecting data would enhance the reliability of the results (McMillan & Schumacher, 2010). This study utilised adopted instruments of which high inter-item coefficients (e.g., Cronbach alpha) had been performed on the Likert-type instruments.

The test-retest reliability measurement for the FSILSQ instrument were calculated statistically by means of Cronbach's alpha coefficient (Litzinger et al., 2007; Livesay, Dee, Nauman, & Hites, 2002; Zywno, 2003). In addition, this study was piloted on 40 learners and the reliability coefficients (Cronbach alpha) were computed. The pilot study revealed that a Cronbach alpha coefficient of visual/verbal was 0.69, sensing/intuitive was 0.72, active/reflective was 0.61 and sequential/global was 0.54. These reliability coefficients show that, for each dimension, the FSILSQ was greater than the cut-off value of 0.5. Thus, it has an acceptable level of reliability for research use. Moreover, the comparison of reliability report (alpha values) from the pilot test with established research studies shows that the reliability values were nearly the same.

Reliability of the CCSSE classroom observation tool has been checked for reliability through extensive testing (Mandarino & Mattern, 2010). A Cronbach's alpha of 0.75 was achieved which was found to be reliable.

Validity

Validity is often defined as the extent to which an instrument measures what it intends to measure (Blumberg, Cooper, & Schindler, 2005). Validity of a research instrument assesses the extent to which the instrument measures what it is designed to measure (Robson, 2011). It is the degree to which the results are truthful so it requires a research instrument (questionnaire) to correctly measure the concepts under study (Pallant, 2011). Validity is defined in quantitative research, as the extent to which any measuring instrument measures what it is intended to measure (Thatcher, 2010). But, in qualitative research, it is when a researcher uses procedures to check for the accuracy of the research findings (Creswell, 2014). According to Willis (2007), validity has two important parts: a) internal (credibility), and b) external (transferability). Internal validity specifies whether the results of the study are authentic because of the way the groups were selected, data were documented or analyses were accomplished and whether the study can be repeated.

To ensure validity, Last (2001) suggested that researchers could employ suitable strategies, such as triangulation, extended contact, member checks, saturation, reflexivity and peer review. Last (2001) defines external validity as whether the finding obtained from one study are transferable to other groups of interest).

Validity tests are divided into four types (Creswell, 2005; Pallant, 2011). They are: (i) content validity; (ii) face validity; (iii) construct validity; and (iv) criterion-related validity. In this study, face validity, content validity, construct validity and concurrent validity were established. Gall, Gall and Borg (2007) define “face validity” as the extent to which a causal, subjective inspection of an instrument’s items indicates that they cover the content that the instrument claims to measure. In this study, face validity was established by giving the instruments to a panel of experts who determined the relevance of the research.

Content validity, according to Davies and Hughes (2014), Leedy and Ormrod (2013), and Sahu (2013), refers to the degree to which the tool completely evaluates or measures the concepts of interest. In other words, “content validity” is about checking the operationalisation against the relevant content domain for the construct. It is usually established by consensus among content experts. Miller, Linn and Gronlund (2009) believe that development of a content valid instrument is typically achieved by a rational analysis of the instrument by experts (ideally three to five) familiar with the construct of interest. In this

study, the questionnaire instruments employed covered all the basic constructs of the research problem and all items were reviewed by experts for readability, clarity and comprehensiveness. A team of experts (two doctoral students, subject advisor and two teachers) content validated the instruments used in this study to see whether they corresponded to what the researcher intended to be covered by the test. Thus, content validity of the test was also established by the pilot study.

Leedy and Ormrod (2005) explain that external validity implies the extent to which research results can be generalised. In this study, the researcher used multiple data collection methods and also included representational samples from learners and teachers, thus establishing the external validity.

3.6.2 Quality criteria applicable to the qualitative research design

Credibility

Credibility, according to Golafshani (2003), refers to the confidence one can have in the truth of the findings that can be established by various methods. Three credibility methods are triangulation, member checking and document analysis. Triangulation is defined by Silverman (2000) as an attempt to get a true view of a situation by combining different ways of looking at it or different findings. In this study, data from multiple sources (i.e. questionnaires, interviews and classroom observations) were employed. Member checking, according to Creswell (1994), is a technique used by researchers to improve the accuracy, credibility and transferability of a study. In this study, member checking was done at the conclusion of the study by sharing all of the findings with the participants involved. This allows participants to critically analyse the findings and comment on them to establish whether they provide a true account of what they describe. This was necessary to provide findings that are authentic, original and reliable. Document analysis, according to Creswell (1998), involves examining elements of the documents that do not support or seem to dispute patterns or clarifications that emerge from data analysis. This was necessary in this study to revise, broaden and confirm the patterns emerging from data analysis.

Confirmability

Schurink, Fouche and De Vos (2013) define confirmability as the quality of the results, in other words, the degree to which qualitative data and their interpretations can be authenticated

and confirmed by another. The techniques used for establishing credibility, such as data triangulation, investigator triangulation and member-checking, are important for building confirmability. In this study, confirmability was established by reporting findings which were clearly supported by the collected data, and involving other PhD students working in a similar field to verify the interview transcripts and the coding of the emerging data independently to ensure that the researcher's interpretations are beyond doubt and that an audit trail has been created.

Dependability

Dependability, according to Denzin and Lincoln (1994), refers to the stability of the findings over time and their confirmability to the internal coherence of the data in relation to the findings, interpretations and recommendations. Lincoln and Guba (1985) and Padgett (2008) believe that an audit trail can be used to establish dependability and confirmability simultaneously. In this study therefore, detailed notes regarding data collection, data analysis and any modifications made were used to verify the accuracy of the findings to achieve dependability. This detailed report furthermore contains convincing evidence that the findings did indeed occur as stipulated in the report. All these details, according to Schurink et al. (2013), enable other researchers to repeat the inquiry and obtain similar results.

Transferability or applicability

Transferability or applicability, as defined by Schurink et al. (2013), means that other researchers can apply the findings of the study to their own research or generalise the findings to another context. Although the generalisation of qualitative findings is usually problematic, the theoretical framework on which a study is based, as well as triangulation, is to establish procedures which can be applied to improve the transferability of a study's findings (Schurink et al., 2013). In this study, the researcher made certain that the focus of the study centred on concepts such as learning styles, learning style-based instructions and learners' achievement in physical sciences. Transferability was further guaranteed by means of triangulation in the sense that multiple participants and respondents (see section 3.6) and several data collection methods (see section 3.7) formed part of the empirical study (De Vos, 2005).

3.7 Ethical considerations

Strydom (2013b) defines ethics as

> "a set of moral principles which is suggested by an individual or group, is subsequently widely accepted, and which offers rules and behavioural expectations about the most correct conduct towards experimental subjects and respondents, employers, sponsors, other researchers, assistants and students" (p. 114).

Accordingly, Strydom (2002) and Cooper and Schindler (2006) believe that the objective of ethics is to ensure that no one is harmed or suffers from the consequences of research activities and that data are not acquired at the expense of the research participants. This statement was affirmed by Leedy and Ormrod (2005) who pointed out that participants in a research project should understand the nature of the study clearly and must be willing to participate in the study.

The following ethical considerations were continuously borne in mind: obtaining informed consent, protecting vulnerable research participants, the non-violation of privacy and the actions and competence of researchers (Babbie, 2008; Strydom, 2013).

Obtaining informed consent

At the start of this study, full ethical clearance for human research through interviews and questionnaires was sought according to the Wits Guidelines for Human Research Ethics Clearance Application (Non-medical). The researcher applied to Wits University Human Research Ethics Committee (Non-medical) for ethical clearance to conduct this research. The research proposal, which outlined the procedures, information given to the participants, informed consent forms and copies of all the instruments to be used accompanied the application. The application also included copies of relevant letters and associated forms for each of the parties involved in the study. The committee approved the conduct of this study in Protocol number 2016ECE004D of 29th March, 2016 (see Appendix F).

After being granted ethical clearance by the Wits University Human Research Ethics Committee (Non-medical), the researcher then applied to the Eastern Cape Department of Education (ECDE) for ethical clearance to conduct the research in five schools under their jurisdiction. Again, the research proposal, which outlined the procedures, information given to the participants, informed consent forms and copies of all the instruments to be used accompanied the application. Permission was granted by the Eastern Cape Department of Education (ECDE) (see Appendix G).

Permission was also sought from the principals of the sampled schools, physical science teachers and parents for their learners to take part in this research. An informed consent form, containing the researcher's particulars, together with the purpose of the study and the appropriate ethical principles, was designed and made available to the research participants to assure them of the researcher's adherence to the correct and appropriate ethical behaviour. All the participants were given full knowledge of the purpose; nature and timeline of the study (see Appendices H1, H2, H3, H4, H5, H6 and H7).

The participants were only absorbed into the study after providing the necessary consent. The potential participants were subsequently notified of the following:

Participants' information

According to the university guidelines, this covers a description of the research, a list of what has been communicated to the participants and a clear statement about what the participants were consenting to by becoming involved in the research. Participants also needed to know the procedure to be used in the study so they knew what to expect. Participants always have the right to ask questions, to obtain a copy of the results and to have their privacy respected (Creswell, 2003). The researcher explained to the participants that they could withdraw from the research at any stage. A specific provision was included for allowing the participants to agree to the interview process, since the interview was tape-recorded which was necessary for data gathering and analysis. Signed and dated consent forms were retained for all participants in the research and, as required, examples of all consent forms issued to participants were submitted as part of the ethics clearance process. Assent forms and the involvement of parents were required since most of the research participants were under the age of 18 (grade 11 learners). In addition, the students indicated their assent to participate in the research in writing (see Appendix H2). Other assent forms the students completed included permission to be interviewed (see Appendix H3). These forms were submitted together during the ethical clearance application.

Confidentiality and communication of findings

Cohen and Manion (1989) view confidentiality as a continuation of privacy. This refers to agreements between persons that limit others' access to private information (p. 24). The participants needed to be assured of the researcher's respect for their confidentiality and that,

as argued by Mouton (2001), a summary of the research results would be offered to them. The information gathered was presented in such a way that no name or information that might be identified as belonging to a particular school was disclosed publicly. The research instruments did not require learners and teachers to indicate their names. The participants were assured that the collection of data from the interviews was for academic purposes only.

Anonymity and protection of vulnerable research participants

Cohen and Manion (1989) note that it is often necessary for respondents to be identified, for instance, when reminders have to be sent to those who have not responded, or for follow up interviews that will be conducted with certain respondents. However, when doing scientific research, participants must not be put at risk. Vulnerable populations, such as those under the age of 18 (children), mentally handicapped, illiterate and those with low social status need to be respected. The anonymity of individuals, roles and incidents must also be protected. In order to do this, coding and pseudonyms were used (Creswell, 2003) to ensure respondents' anonymity.

The participants in the study were assured of anonymity and that their responses would be used only for the purposes of the study. In this investigation, every effort was made to avoid putting the participants at risk and to ensure that all participants were respected. Although the participants needed to put their names on the questionnaires so that their learning styles could be correlated to their academic achievements from test results, the results were treated with utmost anonymity.

Non-violation of privacy

The researcher needed to make every effort to protect the information given by the participants. The participants were informed that the research results would be used for research purposes only and that the results of the study would be available to them on request. The researcher took all necessary precautions to protect the privacy of the participants. This was not difficult as the research did not focus on sensitive issues but on learning style preferences which were not seen as right or wrong.

Integrity of the research

Blaxter, Hughes and Tight (2010) believe that researchers can influence their research and

their findings. However, the researcher had no fixed opinions and views about the issues associated with this study and avoided falsifying or inventing findings at all costs, as this is regarded as scientific misconduct according to Creswell (2009). The researcher abided by the national and international standards of research integrity by ensuring the following:

- Honesty in all aspects of research including: presentation of research goals, intentions and findings; reporting on research methods and procedures of gathering data; using and acknowledging the work of other researchers; conveying valid interpretations and making justifiable claims based on research findings.

- Transparency and open communication in declaring conflicts of interest in the reporting of research data collection methods in the analysis and interpretation of data, in making research findings widely available, including sharing negative results as appropriate.

- Caring for and respecting all participants in and for subjects of the research, including the environmental and cultural objects.

- Assurance that the research was conducted according to appropriate ethical, legal and professional frameworks, obligations and standards. These included seeking ethical approval for research from the university, which was granted.

Authenticity of the research

Authenticity is the act of confirming the truth of an attribute of data claimed as true by an entity. Data are held electronically and in paper copies, and are stored on a password protected computer in a locked filing cabinet in the researcher's office and is only accessible to the researcher (and supervisor) affiliated to the study. Data will be deleted and destroyed five years after the publication of results. In addition, a copyright was obtained from the university to ensure that this work is not replicated and reproduced by anyone.

3.8 Data collection procedures

After finalising the draft instruments, they were pilot tested, standardised and validated. Ethical clearance was sought from the university, permission was granted to undertake the research in the sampled schools. Learner questionnaires were administered. Workshops on the

development and implementation of learning-style based instructions were organised for the sampled teachers. This was followed by classroom observation. After concluding learner questionnaires, quantitative data were analysed, which was followed by the commencement of learner interviews for the sampled learners. This was followed by teacher interviews. At the end of the interviews, qualitative data were analysed to elaborate on the quantitative data obtained earlier. The two data were then integrated during the interpretation phase.

Therefore, this study was carried out in two major phases; the initial data collection phase and the main data collection phase. The initial data collection phase started with initial ethical considerations stipulated for research involving human subjects. This was followed by initial classroom observations and interviews with the sampled teachers. Below, each of the data collection phases is explicated.

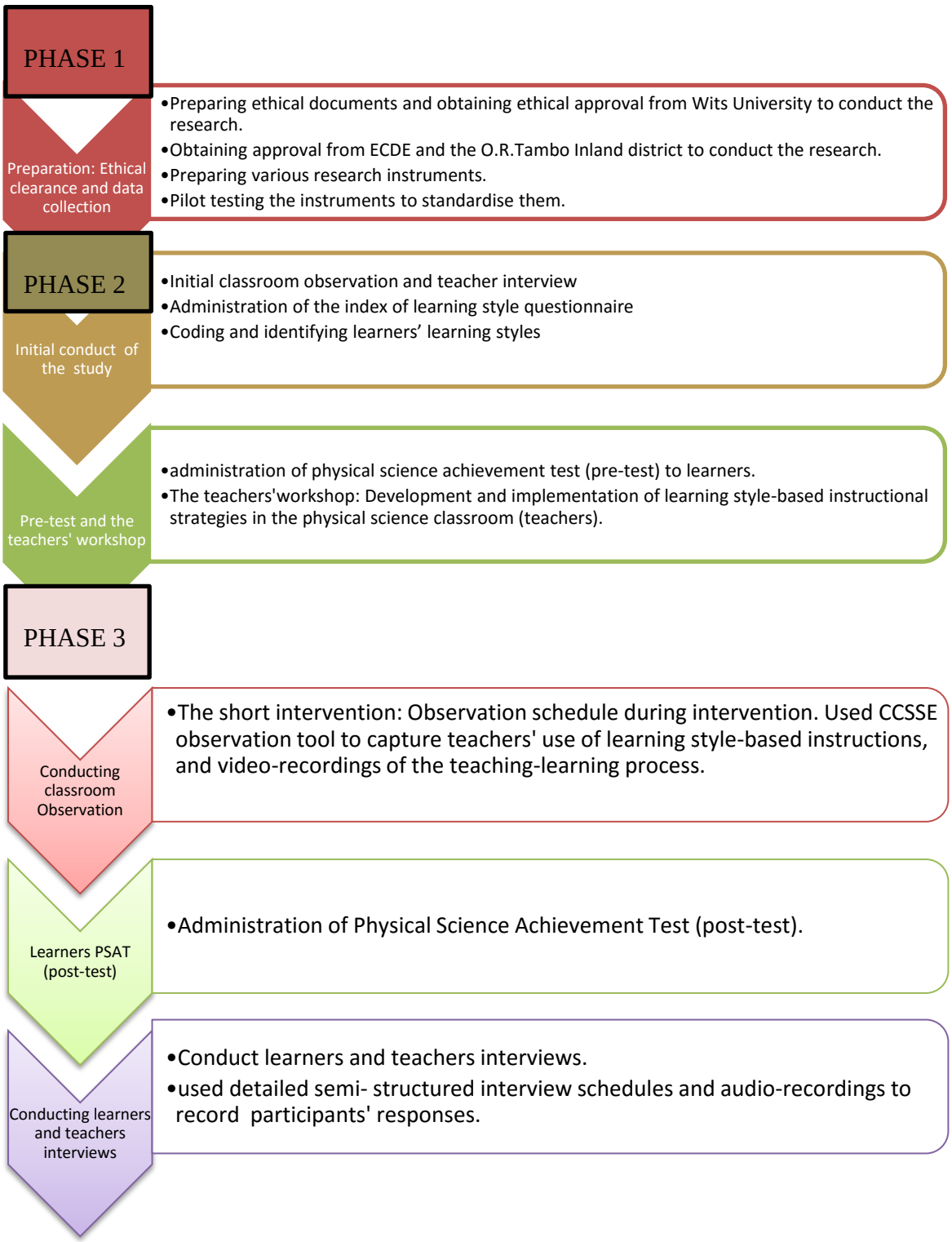


Figure 3.3: Data collection procedures

3.8.1 Initial Classroom Observation

After finalising the sample and tools to be used, and obtaining ethical clearance for the

research from the university, permission was granted and rapport was established between the researcher, teachers and the learners from the sampled schools for the study. Three lesson observations were made on the sampled teachers. This was to enable the researcher to acquaint herself with the kind of instructional strategies mostly used by science teachers in their lessons. The lesson observations were unstructured. The researcher took notes based on how the teachers introduced and gave closure to the lessons, teacher-learner interactions, types of instructional strategies used, class management, questioning skills, teaching resources used and lesson evaluation.

3.8.2 Initial Teacher Interviews

Interviews were conducted immediately after the classroom observation. This was necessary to enable the researcher to understand why teachers used certain kinds of instructional strategies in their science classrooms.

3.8.3 The main data collection phases

The main data were therefore collected in two major phases as shown in the Figure 3.3 above. In the first phase, the index of learning style questionnaire was administered to the learners to identify learners' learning style preferences. This was followed by the coding and identifying of learners' learning styles.

In the second phase, there was the administration of PSAT (pre-test) to the learners. This was followed by the teachers' workshops for intervention. Workshops were organised by the researcher for the four teachers sampled for the experimental study to acquaint themselves with the development and implementation of learning style-based instructions in their physical science classrooms. Thereafter, the sampled classes were taught three sub-units of electricity and magnetism (electrostatics, electromagnetism and electric circuit) for five weeks. Classroom observation was done during the intervention. After implementation of the instructional programmes, it was necessary to get data regarding the achievement of the learners at the end of the five week intervention, so the PSAT was administered again as a post-test. The scripts for the PSAT test were manually marked by the researcher and the results captured into STATA software for analysis. Learner interviews for sampled learners commenced after the PSAT. This was followed by teachers' interviews. After concluding learner and teacher interviews, qualitative data were then analysed. This explained or

elaborated on the quantitative results obtained in the first phase. Qualitative data built on the quantitative data and the two types of data were connected during the interpretation phase of the study.

3.8.3.1 Procedures of learner questionnaire administration

The FSILSQ and the PSAT were the two main questionnaire instruments administered to the learners over a period of a month in five high schools in Mthatha. Prior arrangements were made between the researcher, the school principals, science teachers and learners. Rapport was also established between the learners and the teachers before the administration of the questionnaire.

Procedures of FSILSQ administration

Before administering the FSILSQ, an oral description was given to teachers and learners about the questionnaire and the benefit of completing the questionnaire. Learners were advised to fill in the questionnaire carefully and choose the alternative that could best describe or spell their opinions.

The questionnaire was administered to the 245 learners from all the sampled schools, who submitted consent and assent forms, in the presence of their science teacher and the researcher in their intact classrooms during a free period on Friday in July, 2017. The participants were assured of the confidentiality of their replies. The instructions on the front of the questionnaire were clear and the questionnaire was not cramped in appearance. These were points highlighted by Blaxter et al. (2010) as well as Wellington and Szczerbinski (2007) and taken into account when administering the questionnaire. The researcher informed the participants that they were free to ask their teacher or the researcher if they were unsure of the meaning of any of the questions.

On average, 89% of the learners were able to complete the questionnaire within 40 minutes. When the learners handed in their questionnaires, the science teachers checked to see that the questionnaires had been fully completed and subsequently handed the questionnaires to the researcher. The social setting was made friendly as much as possible to the participants.

Procedures of PSAT test administration

One week after the administration of the FSILSQ, the PSAT was administered as a pre-test to

the learners. Before completing the questionnaires, learners were verbally reminded that their knowledge about electricity and magnetism was sought in those questionnaires. As can be seen from the appendices, all questionnaires also had written instructions to this effect.

Immediately after the intervention, the last questionnaire – PSAT – was administered again as a post-test and as part of their monthly test in all the five sampled schools. The learner questionnaires were administered on different days for each of the five schools. Each completed questionnaire was given a code (a learner code and a school code). For example, SA-L1 means school A, learner 1, ensuring that different questionnaires completed by the same learner got the same code.

3.8.3.2 The teachers' workshops

Grade 11 science teachers sampled for the study were invited to participate in a three-day workshop organised by the researcher with consent from the sampled school principals and with the assistance of the district subject advisor. Various teaching and learning strategies were identified and discussions were held on how they were to be developed and implemented in the science classroom. For each teaching style, instructional materials and guidelines for using them were prepared.

The last day of the workshop was focused on lesson preparations and group presentations. These group presentations took different forms depending on the lesson objectives of the subject matter. Each presentation was followed by feedback from the researcher and the audience (see details in section 4.1)

3.8.3.3 The short intervention

The instructional strategies that were developed during the workshop were implemented in the science classrooms for a period of five weeks in the teaching of "electricity and magnetism". The researcher observed and recorded the teachers' use of learning style-based instructions in the classroom during instructions. Observation tools were used to document how often the teachers matched teaching styles to learners' learning styles, as well as teachers' submission of feedback to the classes. Learners' participation in the teaching/learning process was also recorded using observation schedules.

At the end of the intervention, learners were examined in physical sciences to find out the

impact of the intervention on their learning outcome (see details in section 4.4).

3.8.3.4 Conducting Learner Interviews

Individual interviews were conducted after the completion of PSAT post-test just after the intervention. As already noted (see section 3.5.3), four learners were purposefully selected from each of the four schools used for the experimental study. Learners were selected based on: (1) their consent to participate; (2) their extremely high or low performances on the PSAT having the same learning styles combinations; and (3) extremely high or low performances on the PSAT but with different learning style combinations. Extremely high and low performing learners were identified from the descriptive statistics in the first phase of the study. As a result, 16 participants were selected from the four sampled schools. All genders were represented in the interviews. The researcher believes that it was important to conduct these interviews as the information gained from high and low performing learners and all genders could be of great use by teachers and other learners.

In each school, learners were contacted two weeks prior to the meeting to ensure that learners were available. The conducts of the interviews were held at each school in the science laboratory after school hours in one day, and the interviews lasted for 30 minutes. The purpose of the interview was explained to the learners. The learners were given assurances that the interviews were confidential and for research purposes only. The social setting was made friendly as much as possible to the participants. Interviews started with the researcher introducing herself and asking the respondent to do likewise. The learners also consented to the use of audio-tapes to record interview sections. The audio-tapes were used to provide a means of reviewing the setting and getting the views of other professionals (Fraenkel & Wallen, 1990). Thereafter, in a relaxed atmosphere, it was pointed out that the interview was not an interrogation but rather a discussion of the learners' ideas about physical science, their cultural backgrounds, their learning styles, the instructional strategies used by their teachers and their academic achievement in physical sciences. The interviews were semi-structured (see Appendix C) in that the interviewer followed standard questions but added one or more individually tailored questions to seek clarification or probe a person's reasoning (Leedy & Ormrod, 2013). Such a method of data collection is useful in exploratory types of research (Sahu, 2013) to allow the researcher to get more detailed information in a flexible manner and avoid misinterpretation. However, it was also time-consuming, and the presence of the

interviewer could have affected the learners, thus hampering the quality of the data**.**

3.8.3.5 Conducting teacher interviews

Teacher interviews were conducted immediately after learner interviews. Interviews were conducted in each science teacher's office, usually inside the laboratory. It was also made known to the teachers that the interviews were to be tape-recorded and, as such, the researcher sought consent from the teachers to tape-record their interview sections. The audio-tapes were used to provide a means of reviewing the setting and getting the views of other professionals (Fraenkel & Wallen, 1990). The teachers preferred to have only one interview due to time constraints. On the average, each teacher's interview took between 30 and 40 minutes. Teachers' interview responses were later transcribed.

3.8.3.6 Lesson observations

The researcher conducted observations of classroom sessions taught by five study participants. In total, three lessons were observed from each sampled teacher. One lesson observation was made from each teacher per week. The essence of the class observation was to ensure that the sampled teachers were implementing what was expected of them during the intervention. The teachers and the learners also consented to the use of video-tapes to record observation sections. The video-tapes were used to provide a means of reviewing the setting and getting the views of other professionals (Fraenkel & Wallen, 1990) in order to reduce bias and some degree of subjectivity as a researcher has a unique background and way of perceiving things. The researcher performed the classroom observations using the classroom observational tool which is an element of the Community College Survey of Student Engagement (CCSSE), a project of the University of Texas at Austin (see section 3.5.5).

In general, data were gathered using existing instruments. The advantage of using existing instruments in collecting data is that it saves time and cost. In the qualitative study, interviews were conducted which resulted in a large amount of data collected in a short space of time, as the interviewees were willing to share the information, since the researcher had pre-set questions ready to ask the participant. Through the use of a tape recorder, the researcher obtained a large amount of data, which was later transcribed and analysed. The rationale for using a tape recorder was that it allowed for a fuller record than written notes. It also allowed the researcher to concentrate on other aspects of the interview, rather than taking notes. The

disadvantage of using a tape recorder is that participants may feel uncomfortable with it; in this study, however, the subjects were comfortable with the researcher using a tape recorder during the interviews.

By making use of this technique, the researcher was able to get responses from the set questions, as well as explanations on issues which arose from these questions (Struwig & Stead, 2001; De Vos et al., 2005).

A challenge encountered by the researcher in this research was that of coping with unexpected events. Because of the busy schedule of the teachers in the five schools, the initial interviews did not take place at scheduled times.

3.9 Data analysis and presentations

Data analysis, according to Henning, Van Rensburg and Smit (2004), refers to interpretation and understanding of the raw data to respond to the aims of the study and the research questions. Thus, data analysis is about the search for explanation and understanding in the course of which concepts and theories are advanced, considered and developed (Bosman, 2015). Therefore, both the quantitative and qualitative data were analysed separately and integrated at the final phase of data analysis. The procedure for data analysis is represented in the figure below:

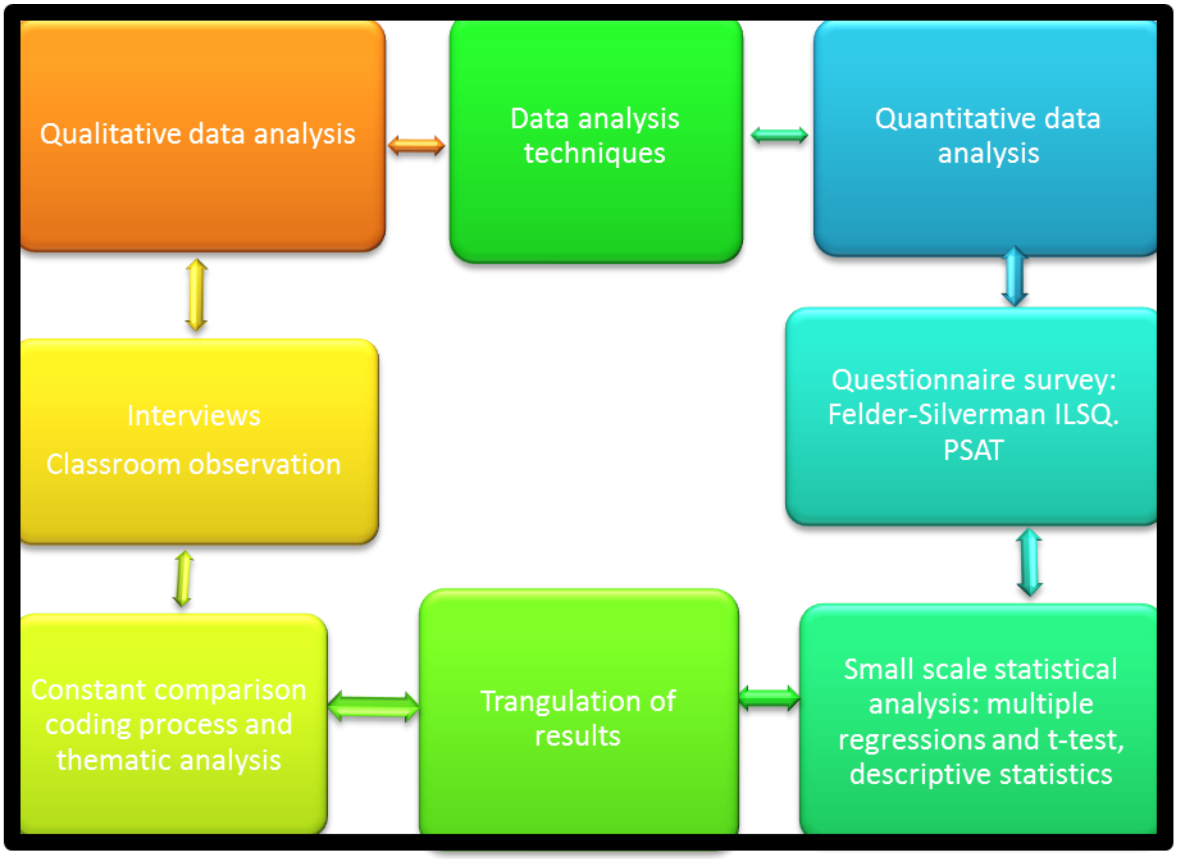


Figure 3.4: Procedure of data analysis for mixed-methods design

3.9.1 Analysis of the quantitative data

The FSILSQ and the PSAT are quantitative data tools therefore, the scores were summarised statistically and were subjected to rigorous statistical analysis. The information from the FSILSQ was manually entered into Microsoft Excel spread sheet for the process of data cleaning. Data cleaning, according to Haughton and Stevens (2010), involves working methodically, question by question, to ensure the data are as accurate as possible. In this study, the data cleaning process involved checking whether the data were within the expected parameters and ranges of the responses, and that data were not missing.

In order to analyse the data that addressed each one of the research questions and the hypothesis in the quantitative part of the study, the researcher used both descriptive statistics and inferential statistics. Creswell (2012) argues that descriptive statistics indicate the general tendencies in the data and the spread of scores, while inferential statistics (mainly multiple regression and t-test) allow for the analysis of data from a sample in order to test a hypothesis. According to Fraenkel, Wallen and Hyun (2005), multiple regressions are

statistical techniques used to determine a correlation between a criterion variable and a predictor variable. Employing multiple regressions determined how Felder-Silverman's learning and teaching styles (independently and in combination) correlated with or measured learners' academic achievements in physical sciences. In addition, a sample t-test was employed to analyse the pre- and post-test. The independent sample t-test was used to test if there was a statistically significant difference in academic achievement among the four Felder-Silverman learning style dimensions.

3.9.2 Analysis of the qualitative data

Teachers' and learners' interviews

Qualitative data analysis consists of identifying, coding and categorising patterns found in the data (Bryne, 2001). To get started, predetermined categories and themes were selected in accordance with practices outlined by Hatch (2002) and these categories were informed by the research questions. These categories are as follows: influence of learners' home background on their learning styles preferences, influence of the way learners were raised on how they relate to their science teacher in the classroom, learning styles learners from typical traditional home backgrounds prefer, influence of learners' home cultural practices on their learning at school, teachers' understanding of culture and its impact on their teaching, and so forth.

These categories were further divided into subcategories to aid data analysis. The researcher then reviewed the data using a constant comparison coding process (Holloway & Wheeler, 2010; Yin, 2015). Constant comparison coding involves repeated re-readings of the transcripts to identify and then refine and consolidate codes and concepts. The resultant codes provided a basis on which to compare the interviews. The researcher read each transcript in turn and used a large chart on which to note ideas and key words that the interviewees had used. As concepts arose which had been previously mentioned, the researcher made a note of the commonality, and then reviewed the notes to identify similar concepts that could be consolidated. The researcher broke the data down into discrete parts and constantly compared these for similarities and differences to extract the phenomena that were embedded in the data. Following that, the researcher re-read each transcript in the context of the identified concepts and looked for the expression of ideas that were either consistent with, or contradictory to the noted concepts. The researcher repeated this process until she was

satisfied that all significant ideas and constructs had been identified. The researcher then performed a final analytical comparison of the identified codes to further refine and consolidate them and to determine which research question or questions they addressed. The researcher systematically related these core codes to other codes and expanded to match the predetermined themes and sub-themes. A list of codes was made and information related to each code was identified throughout all interview responses and classroom observations for interpretation.

To verify the interviews, the researcher asked the teachers and the learners if they would check the transcriptions and confirm that they were a correct reflection of our discussions. They agreed and therefore copies of the transcriptions were sent to all the respondents. The respondents received the transcriptions and confirmed that they were a correct reflection of our discussions, and as such, no corrections were required.

Classroom Observations

Both quantitative and qualitative data emerged from the observation tools. The researcher watched all the videotaped lessons and produced scores for each teacher's instructional practices. The scores were analysed together with the scores obtained from the classroom observation tools. The quantitative data used Likert scale responses which resulted in numerical scores that indicated whether the teacher was implementing learning style-based instructions and the level of student participation and engagement observed in the classroom. Total scores were obtained for all the 38 items in the instrument and for each of the six sections. A lower score implies that the nature of instruction commonly practiced in the science classroom was aligned to the learners' learning style preferences. The highest scores indicate unmatched instructions. The qualitative data of the CCSSE were mostly comments which were treated in the same way as the interview transcripts.

3.10 Chapter summary

In this chapter, detailed descriptions of the research design, the sample and the justification for its selection, the data collection procedures and the data analysis frameworks were given and discussed. The description of methodology detailed the rationale for the strategies used and the justifications for the instrumentation. Attention was also given to a reflective overview of the relevant features of validity and reliability for quantitative and qualitative data, together with issues of validity and reliability in this study as well as ethical

considerations in data collection, analysis and dissemination.

The chapter that follows outlines the development and implementation of learning style-based instructional strategies as a tool for the experimental study.

CHAPTER FOUR
INSTRUCTIONAL MATERIAL DEVELOPMENT

4.0 Introduction

The preceding chapter deliberated the research design, and methodology. In this regard, a mixed methods sequential exploratory design was employed in this study, highlighting the dependability and validity of the measuring instruments and ensuring an ethical approach. This was followed by a discussion of the data collection procedures and data analysis. The chapter concluded with a summary.

In this chapter, the researcher specifically discusses the insights and criteria for developing learning style-based instructions from the initial data collection phase. The researcher further discusses the teachers' workshop, how the instructional materials for this study were developed for implementation in the science classrooms, what insights guided the development of the materials which were implemented in the four high schools sampled for the study to cater for learning style differences among learners in the science classroom. Furthermore, the chapter also discusses the short intervention process.

4.1 Insights and criteria for the development of the instructional materials

The study aimed to design and implement a learning style-based instructional strategy relevant for the South African high school science context to determine the impact of the intervention on learner achievement in the topic of electricity and magnetism. This section gives an insight and the criteria for developing a learning style-based instruction.

Data were gathered through initial interviews with teachers and insights were guided by pre-tests and national imperatives. Further insights into the development of the materials were guided by learner conceptions and misconceptions about physical science as a subject. Five key educationists and 1 learner were selected from each school, and were specifically chosen because they dealt with teaching and learning (also by advising teachers) issues in their schools/institutions. Some were also engaged in teaching and learning issues nationally.

The purpose of the interview was to find out whether the key educationists supported the idea of developing a tool which could be used to teach learners according to their learning styles to augment their understanding and achievement in physical sciences

From the recommendations of the key educationists, learning style-based instructional strategies, adapted from Felder-Silverman learning style model, were developed.

The study summarises the responses of the key educationists to the overall interview question: "What criteria can be used to develop learning style-based instructional strategies that would be relevant to the South African high school educational context?" Further specific questions guiding this process were:

- What do you understand about learning styles?
- Does your school make use of any instruments that help science teachers identify their learners' learning styles in a high school context?
- What do you understand by learning style-based instructional strategies?
- Is there a place for using learning style-based instructions as a framework for teaching and learning in the high school context?
- What kind of instructional strategies would be useful in a high school science education context?
- What would you expect from such a tool?
- What criteria do you think should be used when developing such an instrument or tool so that it is relevant to South Africa?

The following predetermined themes guided the interviews with the key educationists:

Learning styles

All the participants have some knowledge of learning styles. They responded as follows:

- How learners receive and process information from the teacher.
- The different ways learners deal with information.
- The different ways learners approach the learning situation.
- Learners learning differently in a learning environment.

Use of learning style tool to identify learning styles

Responses from the teachers indicated that learning style assessment tools were not used in most of the high schools across the study context. From the interviews, it seems that there is a need for a learning style assessment tool which supports teaching and learning in the high school context. This study provides one solution to develop the awareness of learning styles among both learners and teachers.

Learning style-based instructional strategies

The respondents indicate that they have an idea of learning style-based instructions. They narrated:

- Learning style-based instructions are teaching strategies that consider learners' learning styles in the classroom context.
- Learning style-based instruction is an approach by which a teacher incorporates various methods into his/her teaching, in order to reach out to the majority of the learners.
- Teaching strategies for different learning styles.
- Teaching strategies a teacher uses to accommodate learners' diverse learning styles with or without the use of technology.

Learning style-based instructional strategy as a framework for teaching and learning in the high school context

All the key respondents established that there was a place for the use of learning style-based instructional strategies as a framework for teaching and learning in a high school. They commented:

- Knowledge of learning style-based instructions would help teachers to cater for the differences learners bring to the science classroom.
- Knowledge about learning style-based instructions could assist teachers to adapt their teaching styles to suit the dominant learning style in their classes and to enhance learner performance in the subject.

From the interviews, it appeared that the respondents felt there was a place for using learning style-based instructional strategies as a tool in teaching and learning in a high school science context to improve learner learning outcomes.

Useful teaching tool for the high school science context

Different views were expressed about the kind of tool that would be useful for the high school science context. There were those who felt that a learning style-based instructional tool would be suitable for the South African high school science classrooms. Science teachers would know how learners learn and, as such, design instructions that are congruent with the learners' learning styles.

Three respondents argued that the instructional tool should encourage learners to be innovative, reflective, active learners in the teaching-learning process.

In summary, the key educationists argued for an uncomplicated learning styles tool. This would allow learners to talk about their past learning experiences, to think about how they learn and open up other learning possibilities that they could explore. The informants also expected the tool to lay a foundation for further engagement in discussions with learners.

The participants had varied expectations from the tool. One felt that it should indicate ways to meet the learners' learning needs:

> *I expect the instructional materials to give an indication of effective ways to meet the learners' needs.*

Some participants argued for a tool that looked at how students learnt:

> *I expect the instructional materials to look at one's learning; how it is different, and how it could match one's learning style preference to one's teaching style.*

> *I expect the tool to make students to be reflective of what maximises their learning.*

In summary, the key educationists expected the instrument to focus on how students learnt, give them opportunities to engage in deep thought about their learning and encourage them to reflect on what would increase their learning. Once more, the key educationists stressed that the tool should take into account the South African context.

Criteria for developing a learning style-based instrument relevant to South Africa

Two participants felt that the instructional materials should benefit both learners and teachers:

> *I would support something that would work for both learners and lecturers.*
>
> *The tool should be learner-centred where learners become active participants in their learning.*

Two participants felt that the instrument should allow for the learner's voice:

> *The tool should recognise and acknowledge what the learners brought to the learning situation.*

For example, two of the participants commented:

> *The tool should take into consideration that learners come from different learning backgrounds.*
>
> *The tool to take into cognisance that learners come from different backgrounds and the strengths that learners bring into the learning environment.*

One comment was that the tool should take into account the South African context:

> *The instructional materials should take into account current realities of the South African learning context.*

From the interviews, it appeared that the key educationists expected the instructional materials to be beneficial for both learners and teachers and allow learners to be active participants in their learning. They argued for material that allowed learners to describe their learning experiences in their own words and that affirmed and appreciated what the learners brought to the learning environment. They further argued that the tool should acknowledge and integrate the strengths the learners had in other contexts.

4.2 The teachers' workshops

Grade 11 science teachers sampled for the study were invited to participate in a three-day workshop organised by the researcher with the consent of the sampled school principals and with the assistance of the district subject advisor. Various teaching and learning strategies

were identified and discussions were held on how they were to be developed and implemented in the science classroom. Therefore, the workshop introduced science teachers to a range of techniques that orientated them towards the development and implementation of teaching styles that match learners' learning styles to improve learner achievement in the subject.

At the onset of the workshop, each participant was handed a resource pack made up of the programme outline, FSLSQ questionnaire, compilation of selected articles on learning styles, a pamphlet on Felder-Silverman teaching and learning styles, the CAPS policy document and template for developing lesson plans on electricity and magnetism. These materials were used during the workshop, but could also serve as reference materials for the participants in their teaching endeavours.

On the first day of the workshop, the participant teachers were introduced to the "constructs" of learning and teaching styles. Hence, the day was characterised by frequent intervals of instructions, small group discussions and presentations. On the second day of the workshop, there was a presentation on the development of instructions that match learning styles facilitated by the researchers. A discussion on the steps to follow when developing teaching styles matched to learning styles was held using a PowerPoint presentation. The third day of the workshop was focused on lesson preparations and group presentations. These group presentations took different forms, depending on the lesson objectives of the subject matter. Each presentation was followed by feedback from the researchers and the audience (Appendix I).

4.2.1 Development of learning style-based instructional strategies

According to Keefe (1991), developing learning style-based instructional strategies involves diagnosing individual learning style preferences, determining class strengths and weaknesses, and examining the subject content for the area that may be difficult for learners. Keefe further indicated that learners' prior achievement scores could be analysed by assessing current instructional strategies to determine whether they are adequate or require more modification to the learning environment.

After extensive review of related literature, it became necessary for the researcher to develop instructional strategies that are congruent to the learning style of the learners. This is because,

the large majority of scholarly sources (for example, Ahanbor & Sadighi, 2014; Bas & Beyhan, 2013; Bhatti & Bart, 2013; Felder, 2010; JilardiDamavandi et al., 2011) support the position that learners have preferences for receiving, processing, storing and retrieving material and perform better in school if instructional methodology was adapted to match these preferences. Since the objective of this study has a central focus on the creation of teaching methods and environments that utilise the teaching material and strategies in congruence with the learner's learning style, the matching of teaching and learning styles was explored based on the Felder and Silverman (1988) model.

After a review of the subject content, the lesson objectives and the characteristics of the learners' learning style preferences, the researchers together with the teachers decided on the appropriate teaching methods for each type of learning style preference, bearing in mind the lesson objectives. The following steps were followed when developing learning style-based instructional strategies:

- Analysis of subject content;
- Content analysis in the view of instructional strategies;
- Lesson planning for each sub-topic;
- Pilot testing the lesson plans;
- Expert opinion on lesson plans; and
- Final form of Teaching Programme for implementation.

4.2.2 Analysis of subject content

The concept of "electricity and magnetism" was selected as the content for teaching in this study and was further divided into three sub-topics as follows:

- Electrostatics (Coulomb's Law, electric field).
- Electromagnetism (magnetic field associated with current-carrying wires, Faraday's Law).
- Electric circuits (energy, power).

The weighting of the content for each lesson was decided considering the specific aims and the nature of the content, with regards to the assessment taxonomy. Some of the sub-topics

were descriptive; some were hands-on, while others had content that required experiments or demonstrations to understand the concepts and their underlying principles.

4.2.3 Content analysis in the view of instructional strategies

The topics selected for teaching were further analysed keeping instructional strategies in mind. The purpose of content analysis was to validate whether an instructional strategy would be more appropriate for each sub-topic. For example, when the topic "Coulomb's Law and electric field" under "electrostatics" was analysed, it was found to be demonstrative, descriptive and deductive. This implies that different instructional strategies should be utilised to teach the learners with different learning styles in the science classroom. For the visual/verbal learners, demonstration and discussion teaching methods were most appropriate for teaching these topics whereas, for the active/reflective learners, brainstorming and case study were most appropriate, for the sensitive/intuitive learners, problem solving and discussion were more appropriate and for the sequential/global learners, presentation and role plays were most appropriate for teaching these topics.

The sub-sections that follow illustrate the nature of instructional strategies, preparation of the instructional materials and guidelines for using them. Table 4.2 below illustrates the different instructional materials selected as appropriate for the different learners in the science classroom. For each teaching style, instructional materials and guidelines for using them were prepared (see Appendix J).

Table 4.1: Instructional strategies for teaching different learning style preferences

		LEARNING STYLES							
		Sensitive	Intuitive	Visual	Verbal	Active	Reflective	Sequential	Global
TEACHING STRATEGIES	Demonstration/Experimentation	X		X		X			
	Games and simulations		X	X		X			
	Learning based on problem solving	X				X			
	Role playing		X			X			X
	Presentation	X		X			X	X	
	Discussion panel		X		X	X			
	Brainstorming				X	X			X
	Case study		X				X		X
	Question and Answer Method	X			X		X	X	
	Project Method		X			X			X

The instructional strategies selected for Perception, Processing, Input and Understanding learners are presented in Figure 4.1below:

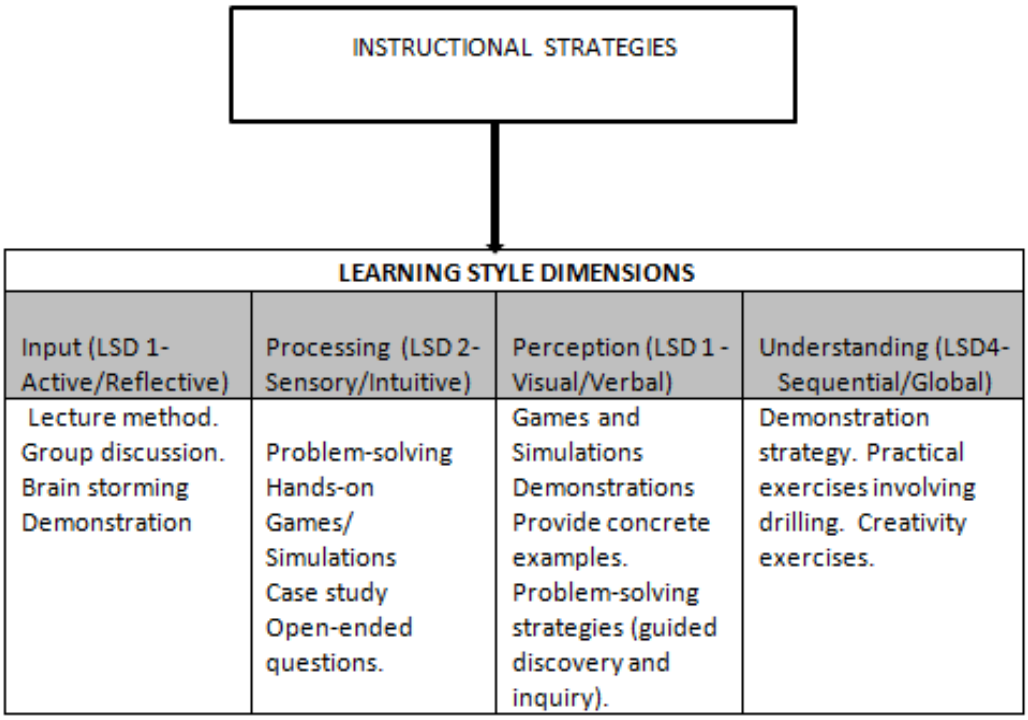


Figure 4.1: instructional strategies for input, processing, perception and understanding learners

4.2.4 Lesson Planning

Lesson planning is an integral part of the instructional process (Gloria & Oluwadara, 2016). It is a creative process, a step-by-step detailed guide for how a lesson should be taught. To provide different learning experiences of the same content to learners of different learning style preferences, it became necessary to plan different instructional strategies according to the learning style preferences of learners that could be implemented in the same group of learners by the same teacher at the same time. Therefore, a systematic structure of lesson planning was developed and all lesson plans were prepared according to that structure (nine major components of the lesson plan) (see Appendix K).

In the lesson planning phase, the researcher and the teachers considered the subject content of each topic and sub-topic under electricity and magnetism (e.g. Coulomb's Law, electric field), the duration of the content as stated in the CAPS document, lesson objective (learners should be able to state Coulomb's Law) and the main knowledge to be explored. A decision was also made on the teaching strategies that would be suitable for teaching such a topic considering the different learning styles in the science classroom. For example, for the first topic on "electrostatics", demonstration, discussion and use of charts methods were selected

for visual/verbal learners (see Appendix K). Teaching resources, teachers' activities, learner activities and an evaluation of each lesson were included in the lesson plans. In all, 20 lesson plans were prepared by the researcher and the sampled teachers on the topic "electricity and magnetism" which were implemented in the science classrooms during the intervention.

4.2.5 Getting expert opinion on lesson planning for validity and reliability

In order to validate and increase the reliability of the lesson plans, all the lesson plans prepared by the researcher and the sample teachers for the four main Felder-Silverman learning style preferences were given to key informants (a linguist, the supervisor, subject advisor and a colleague) for their inputs and recommendations. The linguist was presented with the lesson plans to establish whether the statements were clear and unambiguous. The supervisor, subject advisor, a colleague teacher and a postgraduate student were given the lesson plans to determine the appropriateness of the lesson plans for the study. The key informants suggested some changes, which were subsequently affected, before the actual piloting took place. The feedback and comments from the experts led to the following changes:

- The core concepts were made more detailed to form teacher summaries which were required to be copied as notes by the learners.
- There was an inclusion of other teaching strategies to cater for the sensing/intuitive learners.
- Peer teaching/group work was included to get all learners involved in the learning process.

Thus, face, construct, content validity and reliability were obtained through consultation with the key informants and through piloting the tool.

4.2.6 Pilot testing the lesson plans

To examine the reliability of the lesson plans, they were first piloted with a sample of 40 learners in the researcher's school for two weeks. According to Doody and Doody (2015), "a pilot study is a small-scale version of a planned study conducted with a small group of participants similar to those to be recruited later in the larger scale study" (p. 1074) and is

often implemented to assess the viability of methods, approaches, questionnaires and interviews and how they function together in a particular context. It can also divulge ethical and practical issues that could impede the main study. Fraser, Fahlman, Arscott and Guillot (2018) state that the main aim of pilot testing research instruments is to intensify the possibility of success in the main study by testing the viability of the procedures for recruitment and retention of participants, testing for content validity and face validity of the questions, and assessing the usability (including ease of access and navigation) of the technology employed for administering the questionnaire.

The following were considered as the main objectives of pilot testing the lesson plans before implementation in the main study:

(1) To validate the appropriateness of the length of the content for each lesson.

(2) To generate teaching/learning materials for implementation.

(3) To decide the appropriateness of the teachers' and learners' activities.

The table below depicts the programme followed in piloting the lesson plans with the learners

Table 4.2: Programme for piloting the lesson plans

Type of activity	**Detail of activity**	**Responsibility**	**Purpose**
Initial pilot study 1	Part 1: The researcher used this tool for teaching in her classroom for a week	The researcher	To determine the appropriateness of the tool to assess learners learning and the teacher's teaching strategies.
Initial pilot study 2	Part 2: Learners completing the learner activities included in the lesson plans	Researcher: Learners: (n=40) taking part in the teaching and learning. Learners completing the learner activity.	To determine the appropriateness and suitability of the lesson plans
Main pilot study	The colleague used this tool for teaching learners in the class taught by the researcher.	Colleague teacher. Learners	To gain insight into how feasible the lesson plans are and how learners strengths and weakness were with regards to the learner activities.
Discussion: Focus group	The colleague and the learners discuss about the activities for the learners.	Colleague teacher, Learners and the researcher	To gain insight into how learners strengths and weakness were with regards to the learner activities.

After the pilot testing of the lessons, the learners were requested to write about their learning experiences during the two week period. Valuable information was obtained from the learners that resulted in the revision of the lesson plans.

After the pilot testing and gathering of experts' opinions about the lesson plans, necessary changes in the lesson plans were made. Some teachers' and learners' activities were included and made more detailed, some relevant teaching/learning materials were included for learners' understanding, while some teaching strategies were removed. The teaching plans were finalised for implementation in the physical science classrooms. The lesson plans consisted of the following:

- There were 20 lessons. The classification of total lessons according to different instructional programmes is given in Appendix K.
- Each lesson comprised nine components including day/date, content, core concept, instructional objectives, instructional strategies, teaching/learning materials, teachers' activity, learners' activity, evaluation and assignment.
- 50/60 minutes were allocated to implement each lesson.
- The lesson plan format was common for all the four major learning style preferences: Processing (LSD3) - Active (A) and Reflexive (Re), Perception (LSD1) - Sensitive (S) and Intuitive (I); Entry Channel/Processing (LSD2) - Visual (VI) and Verbal (Ve) and Understanding (LSD4) - Sequential (Seq) and Global (G).
- All the lesson plans were prepared based on the content of "Electricity and Magnetism" of physical science, in grade 11.

Detailed lesson plans of active/reflective instructional programme, sensory/intuitive instructional programme visual/verbal instructional programme and sequential/global instructional programme are given in Appendix K.

4.3 The short intervention

The instructional strategies that were developed during the workshop in the teaching of the topic electricity and magnetism (see Appendix J) were implemented in the science classrooms

for a period of five weeks. Based on the Felder-Silverman model, active learners benefited from group discussions, hands-on activities and projects. Reflective learners benefited from small groups and were provided with ample time for questions, reflections and feedback. Sensing learners benefited from practical work, while intuitive learners were presented with teaching styles delivered in an abstract fashion to stimulate thinking while they reflected on the materials learned. Visual learners benefited from teaching styles given through visual aids, for example, PowerPoint presentations, blackboards, illustrations, graphs, etc., whilst verbal learners received teaching styles that were in the form of discussions, brainstorming sessions and questions and answers. Sequential learners benefited from instructions where terms and concepts were appropriately defined before examples of their applications and implications were explored, whereas global learners favoured instructions presented in a systems-orientated manner.

The researcher observed and recorded the teachers' use of matching teaching styles to learners' learning styles in the classroom during instructions. Observation schedules were used to document how often the teachers matched teaching styles to learners' learning styles, as well as teachers' submission of feedback to the classes. Learners' participation in the teaching/learning process was also recorded using observation schedules.

At the end of the intervention, learners were examined in physical sciences. The learners' scores in the PSAT pre-test and PSAT post-test results in physical sciences were compared to explore the impact of learning style-based instructional strategies on learner academic achievement in physical sciences. Interviews were conducted by the researchers to find out the participating teachers' and learners' perceptions and experiences with the adaption of teaching styles to meet learner needs in the science classroom.

The development of learning style-based instructional strategies was also guided by national imperatives, including matric exam analysis of learner conceptions and misconceptions. According to the chief examiner's report, learners do not do well in questions about electricity and magnetism (see section 1.1) because they fail to contextualise and establish the relationships between current, voltage and resistance as well as connections in a circuit. The material developer (the researcher) addressed these insights by ensuring that learners are taught in a way which is congruent with their learning styles and cultural backgrounds.

4.4 Chapter summary

The chapter aimed to develop learning style-based instructional strategies to be implemented in the physical science classroom in four high schools in Mthatha. In order to do this, initial data were collected from key informants to give the researcher insights into the criteria for developing and implementing learning style-based instructions. To do this, key informants were interviewed to determine the necessary criteria. The key informants expressed different views about the form the instructional material should take. They recommended particular criteria for developing relevant learning style-based instructional strategies. Furthermore, workshops were organised for teachers. The aim of the workshops was to introduce science teachers to an alternative approach to teaching electricity and magnetism. This would orientate them towards the development and implementation of learning style-based instructional strategies as creative teaching techniques to stimulate learning outcomes in physical sciences. At the workshop, various teaching and learning strategies were identified and discussed. These teaching strategies were linked to different learning style preferences in the development of the instructional strategies. Thus, the matching of teaching and learning styles was explored based on the Felder and Silverman model. The chapter further discussed the steps involved when developing learning style-based instructions and the design of lesson plans for the intervention including the validation and reliability processes of the lesson plans prepared by the researcher.

The chapter ended with a discussion of the short intervention in which the learning style-based instructional materials developed by the researcher and the teachers were implemented. The next chapter presents the findings from data collected after the learning style-based instructional strategies were implemented in the science classroom.

CHAPTER FIVE
THE IMPACT OF LEARNING STYLE-BASED INSTRUCTIONS ON LEARNER ACADEMIC ACHIEVEMENT

5.0 Introduction

The analysis of the data collected from the administration of the FSILSQ and the PSAT to the sampled physical science learners is presented. The chapter begins with the outline of the demographic characteristics of the sampled population. Finally, the chapter presents the results of the study based on learning style preferences, academic achievement levels and the relationship between the two in order to answer the following research questions:

1) With regards to the learning style index, what are the prevailing learning style preferences among grade 11 physical science learners based on the index of learning styles questionnaire?

2) What impact, if any, does a learning style-based instruction have on learner academic achievement in physical sciences?

The data were subjected to analysis using a tool that analyses data from a number of perspectives. The aim of the first research question was to determine the prevailing learning style preferences among grade 11 physical science learners of electricity and magnetism. The second research question aimed at determining if learning style-based instructions have any significant impact on the academic achievement of grade 11 physical science learners.

In presenting the quantitative results, the results from the FSILSQ are given first followed by the results of the PSAT.

5.1 Quantitative results

5.1.1 Demographic data

The demographic characteristics of the 245 respondents are indicated in Tables 5.1 and Figures 5.2 and 5.3. The demographic variables include learners' schools, learners' profiles, and learners' gender.

5.1.1.1 Schools' and learners' profiles

The research results presented here are based on a sample population from five schools in Mthatha.

Table 5.1: School Profiles of respondents

SCHOOL CODE	NUMBER OF LEARNERS	%
SCHOOL A	58	23.8
SCHOOL B	55	22.4
SCHOOL C	54	22.0
SCHOOL D	38	15.5
SCHOOL E	40	16.3
TOTAL	245	100

The above sample composition in terms of school profile of learners is also depicted through a bar graph in Figure 5.1.

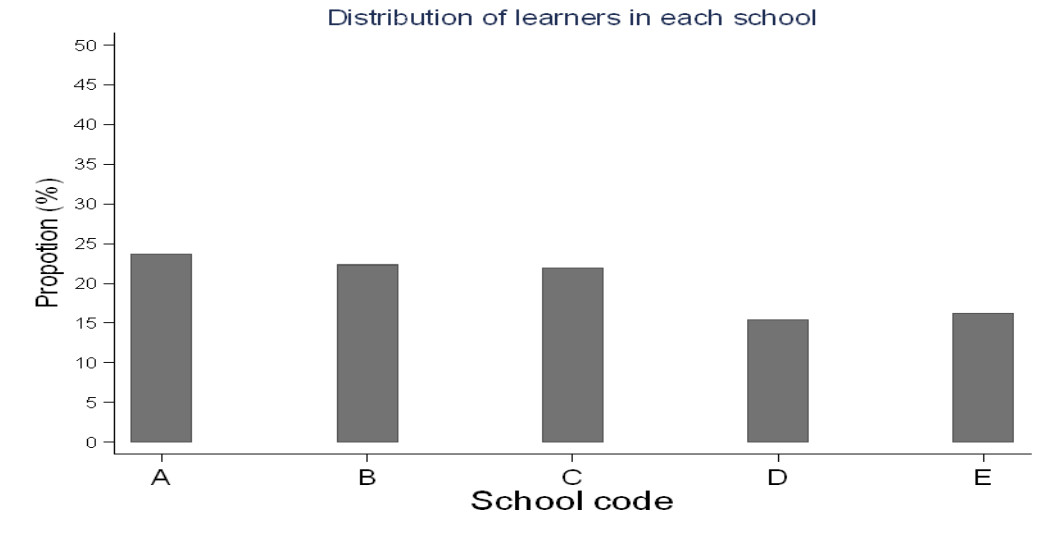


Figure 5.1: Proportion of learners by school

Table 5.1 and Figure 5.1 show that the largest number of respondents came from School A (n=58; 23.8%), followed by school B with n=55 (22.4%) and School C with n=54 (22.0%).

The smallest group of learners came from school D with n=38 (15.5%) and School E provided 40 (16.3%) learners for the study. The targeted sample population of 250 was not achieved due to 10 respondents withdrawing during the data collection process, thus achieving a response rate of 98%.

5.1.1.2 Gender of the learners

Out of a total of 245 learners in the study, Figure 5.2 shows that the majority of the respondents were females (n=158; 64.5%) and the minority were males (n=87; 35.5%).

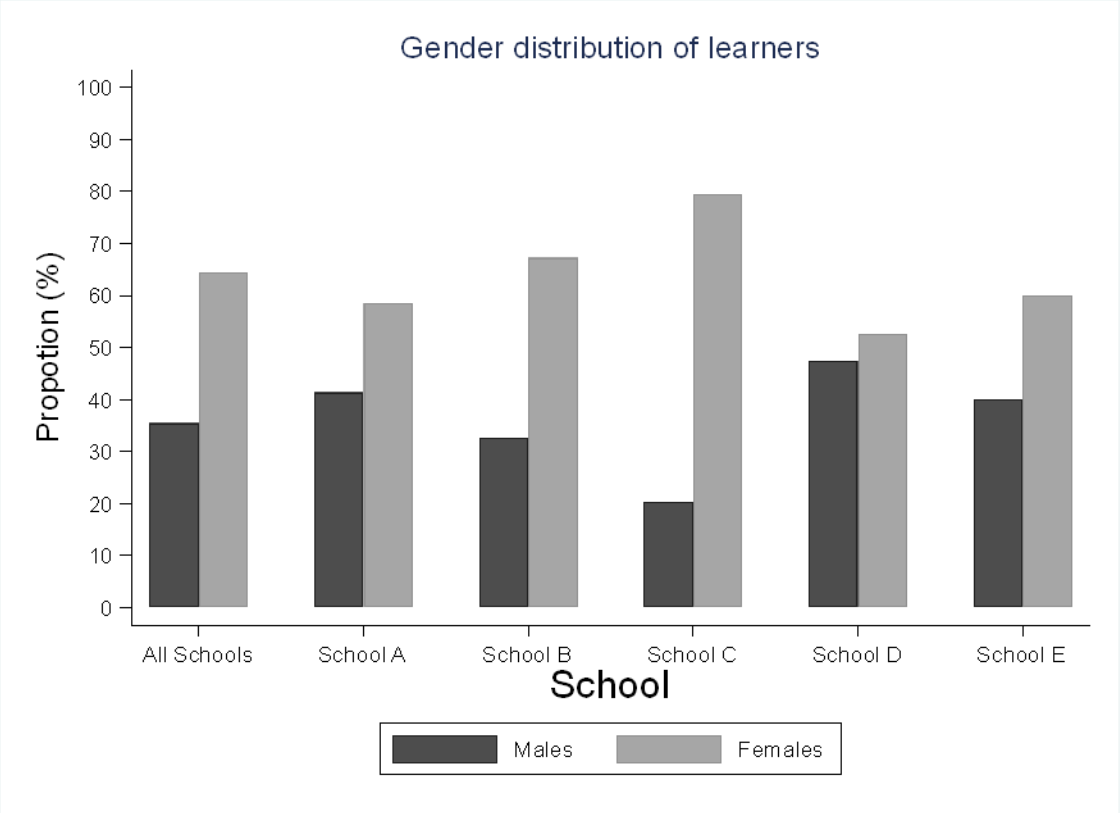


Figure 5.2: Gender distribution of learners in each school

5.1.2 Results from the FSILSQ

This section presents the results from the FSILSQ to answer the first research question with regards to the learning style index, "what are the prevailing learning style preferences among grade 11 physical science learners based on the index of learning styles questionnaire?" This question was answered by looking at both the analysis of the individual items of the

questionnaire as discussed in the sections below.

5.1.2.1 FSILSQ Data Processing

The FSILSQ consists of 44-item questions with 11 questions specifically designed to indicate respondents' preferences for each of the four dimensions (see section 3.5.1). Respondents completed the FSILSQ at the beginning of the study. They were instructed to read each question carefully before selecting one of the two possible answers. For statistical purposes, respondents were given a scoring sheet where they responded to questions by indicating a response with a number "1" or "0" under each column. Total scores for each column were computed by summing the scores of the "a" answers for relevant questions and the "b" answers for the relevant questions under each of the four scales of dimensions. For each of the four scales, the smaller total was subtracted from the larger one to get the overall total for that particular scale dimension. The difference of 1 to 11 and the letter "a" or "b" with the larger total was written below. Table 5.2 below illustrates a scoring sheet from one of the respondents.

Table 5.2: An extract from the scoring sheet on summing learning style scores for a respondent

	ACTIVE/REFLECTIVE			SENSING/INTUITIVE			VISUAL/VERBAL			SEQUENTIAL/GLOBAL	
Q	a	b	Q	a	b	Q	a	b	Q	a	b
1	1	0	2	1	0	3	1	0	4	1	0
5	1	0	6	0	1	7	1	0	8	1	0
9	1	0	10	1	0	11	0	1	12	1	0
13	1	0	14	1	0	15	1	0	16	1	0
17	1	0	18	1	0	19	1	0	20	1	0
21	1	0	22	0	1	23	0	1	24	1	0
25	1	0	26	0	1	27	1	0	28	1	0
29	1	0	30	0	1	31	0	1	32	1	0
33	0	1	34	1	0	35	0	1	36	1	0
37	0	1	38	1	0	39	0	1	40	1	0
41	0	1	42	1	0	43	0	1	44	1	0
	Total for each category										
	ACTIVE	REF		SENSING	INTUITIVE		VISUAL	VERBAL		SEQ	GLOBAL
	a	b		a	b		a	b		a	b
	8	3		7	4		5	6		11	0
Larger - smaller) + letter of larger = learning style preference											
	5a			3a			1b			11a	

From Table 5.2 above, a respondent's learning style profile can be determined for each of the four dimensions on a nominal scale by indicating whether the learner is active or reflective,

sensing or intuitive, visual or verbal, or sequential or global. Table 5.2 given above shows:

- On the active/reflective dimension column of the scoring sheet, a total score of 5a represents a moderate preference for the *active* learning style category in that dimension.

- On the sensing/intuitive dimension column of the scoring sheet, a total of 3a indicates a mild preference for the *sensing* category in that dimension.

- On the visual/verbal dimension column of the scoring sheet, a total score of 1b indicates a mild preference for the *verbal* learning style category in that dimension.

- Lastly, on the sequential/global column on the scoring sheet, a total score of 11a indicates a strong preference for the *sequential* learning style category in that dimension.

Therefore, the learning style profile for the above respondent is active, sensing, verbal and sequential learning style preference, with the strongest preference for a sequential learning style. The researcher examined the respondents' completed questionnaires for accuracy and completeness and entered the dataset using Microsoft Excel to capture and make summaries of the learning style profiles of the respondents. The next section that follows highlights the results obtained from the FSILSQ questionnaire

5.1.2.2 Results of FSILSQ

Table 5.3 shows the learning style profiles of the respondents which are distributed among the four Felder-Silverman Learning Style Dimensions. Table 5.3 shows that, from a total number of 245 respondents in the processing learning style category, 149 of them, representing 60.8%, were classified as active learners, forming the majority of this category while 96 respondents, representing 39.2%, were considered as reflective learners.

Table 5.3: The distribution of learning style preferences among grade 11 learners

Felder-Silverman' s learning style dimensions		Learners' distribution of learning style dimensions by school level					Total	
		School A	School B	School C	School D	School E	n	%
Processing	Active	36	30	39	22	22	149	60.8
	Reflective	22	25	15	16	18	96	39.2
	Total	58	55	54	38	40	245	100
Perception	Sensing	49	44	44	35	24	196	80.0
	Intuitive	9	11	10	3	16	49	20.0
	Total	58	55	54	38	40	245	100
Input	Visual	33	41	38	28	26	166	67.8
	Verbal	25	14	16	10	14	79	32.2
	Total	58	55	54	38	40	245	100
Understanding	Sequential	39	36	39	30	25	169	69.0
	Global	19	19	15	8	15	76	31.0
	Total	58	55	54	38	40	245	100

Considering the perception learning style dimension, from a total number of 245 respondents, 196 (80%) of the respondents were classified as being sensing learners, while 49 (20%) were intuitive learners, with the sensory learning style category forming the majority of this dimension.

Considering the input learning style dimension, from a total number of 245 respondents, 166 (67.8%) were identified as having a preference for the visual learning style, forming the majority, while 79 (32.2%) of the learners were identified as verbal learners. For the understanding learning style category, a majority of the learners, 169 (69.0%), were identified as sequential learners while 76 (31.0%) of the learners have global learning styles.

The above description of the distribution of learners in different learning style categories is depicted in a bar graph (Figure 5.3).

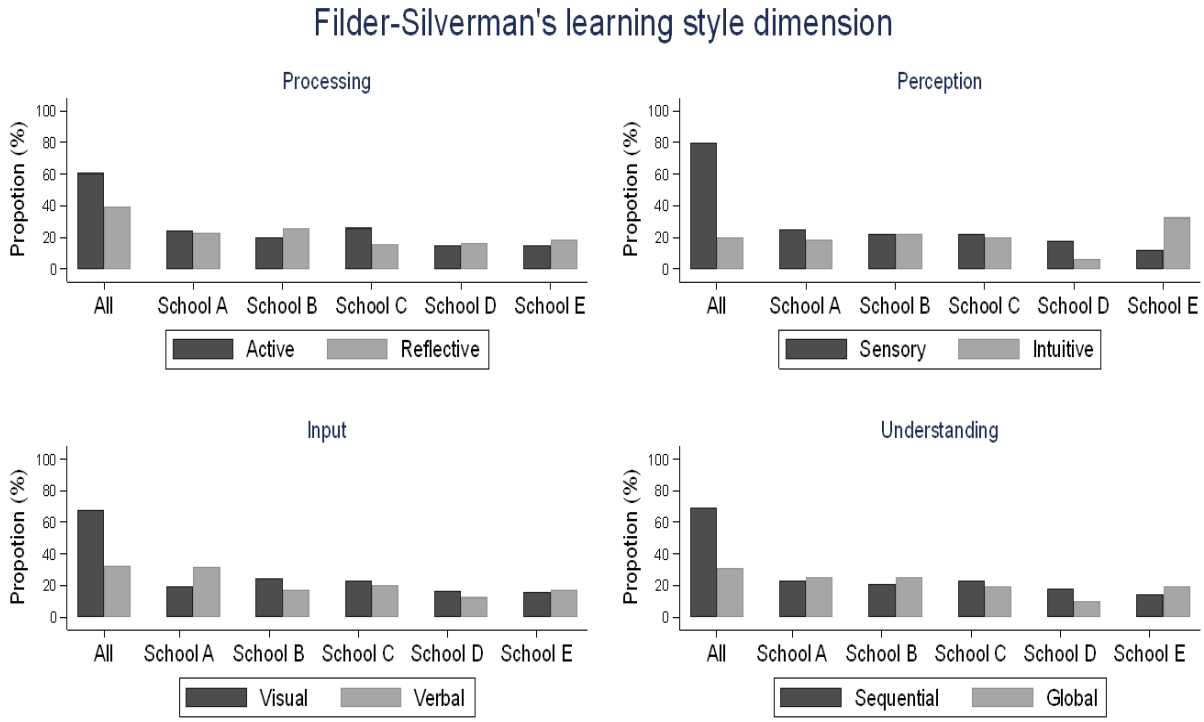


Figure 5.3: Distribution of learning style preferences among grade 11 science learners from the sampled schools

When learning style preferences were analysed by school, the results show that there were more active (n=36), sensing (n=49), visual (n=33) and sequential (n=39) learners compared to reflective (n=22), intuitive (n=9), verbal (n=25) and global (n=19) learners in School A. In School B, there were more active (n=30), sensing (n=44), visual (n=41) and sequential (n=36) learners compared to reflective (n=25), intuitive (n=11), verbal (n=14) and global (n=19) learners. In School C, there were more active (n=39), sensing (n=44), visual (n=38) and sequential (n=39) learners compared to reflective (n=15), intuitive (n=10), verbal (n=16) and global (n=15) learners. In School D, there were more active (n=22), sensing (n=35), visual (n=28) and sequential (n=30) learners compared to reflective (n=16), intuitive (n=3), verbal (n=10) and global (n=8) learning style dimensions. In School E, there were more active (n=22), sensing (n=24), visual (n=26) and sequential (n=25) learners compared to reflective (n=18), intuitive (n=16), verbal (n=14) and global (n=15) learners.

From Figure 5.3, it is evident that the dominant learning style preferences in all the schools are active, sensory, visual and sequential. A few learners have preferences for the reflective, intuitive, verbal and global learning style dimensions.

5.1.2.3 Details per learning style profile

The four learning style dimensions discussed in Table 5.3 were then summarised according to the strengths of the reported preferences for each category for all the learning style profiles of the respondents. For example, if a respondent's score on a particular scale for a particular dimension is 1-3, the learner has a *low* preference for one or the other dimension. Low preference means that the respondent has no strong preference for either dimension (see section 3.5.1), for example, 3a in the ACT/REF category indicates a low preference for active learning.

If a respondent's score on a scale is 5-7, the respondent has a *moderate* preference for one dimension of the scale and will learn more easily in a teaching environment which favours that dimension. If a respondent's score on a scale is 9-11, the respondent has a *strong* preference for one dimension of the scale. He/she may have real difficulty learning in an environment which does not support that preference.

Table 5.4: Details per learning style dimension

Dimension	Category	Number	Low	Moderate	Strong
PROCESSING	ACTIVE	149	83	44	22
	%	60.8	55.7	29.5	14.8
	REFLECTIVE	96	59	26	11
	%	39.2	61.5	27	11.5
PERCEPTION	SENSING	196	92	72	32
	%	80.0	47.0	36.7	16.3
	INTUITIVE	49	23	13	13
	%	20.0	47.0	26.5	26.5
INPUT	VISUAL	166	65	70	31
	%	67.8	39.2	42.1	18.7
	VERBAL	79	50	18	12
	%	32.2	62.2	22.7	15.1
UNDERSTANDING	SEQUENTIAL	169	102	45	22
	%	69.0	60.4	26.6	13.0
	GLOBAL	76	49	16	11
	%	31.0	64.5	21.1	14.4

As already highlighted in Table 5.3, a total of 245 respondents completed the FSILSQ and were assigned to the four Felder-Silverman learning style dimensions. If each dimension is dichotomous (two poles), that makes eight learning style profiles. The results from Table 5.4

show that a majority of the respondents have a low preference for each of active/reflective learning style dimensions (low preference means they are also fairly well balanced on the two (active/reflective) dimensions (55.7%, n=83/61.5, n=59) respectively. However, 44 (29.5%) and 26 (27%) of the respondents have a moderate preference for the active and reflective learning styles respectively. Only few learners have strong preference for the active 22 (14.8%) and reflective 11 (11.5%) learning style dimensions.

On the sensing/intuitive dimension, results show that 92 (47.0%) of respondents have a low preference for a sensing learning style and 23 (47%) have a low preference for an intuitive learning style. However, the results indicate that 72 (36.7%) respondents have moderate preferences for the sensing learning style dimension, while 13 (26.5%) respondents have a moderate preference for an intuitive learning style. Only a few learners have a strong preference for sensing (n=32, 16.3%) and intuitive (n=13, 26.5%).

On the visual and verbal dimensions, the results indicate that 115 (46.9%) of the respondents are well balanced on the visual/verbal dimension, 70 (42.1%) have a moderate preference for the visual dimension whereas 31 (18.7%) have a strong preference for visual learning. Eighteen (22.7%) of the total verbal respondents have a moderate preference for verbal learning with a small number of the respondents, 12 (15.1%), having a strong preference for a verbal learning style.

On the sequential/global dimension, a majority of the respondents, 151 (61.6%), have a well-balanced preference for both sequential and global dimensions, 45 (26.6%) have a moderate preference for the sequential learning and a small number, 22 (13.0%), of the total sequential respondents having a strong preference for the sequential learning style. However, 16 (21.1%) of total global respondents have a moderate preference for a global learning style, with only 11 (14.4%) having a strong preference for a global learning style.

5.1.2.4 Gender differences in learning style preferences among learners

The data were examined to see if there were any relationship between the learning style preferences and demographic factors such as gender. The identified relationships are presented below in Table 5.5.

Table 5.5: The learning style preferences by gender with respect to the total sample

Gender	Number	Processing		Perception		Input		Understanding	
	(n)	Active	Reflective	Intuitive	Sensory	Verbal	Visual	Global	Sequential
Female	158	100	58	32	127	53	106	41	118
%	64.5	67.6	59.8	66.7	64.5	66.3	64.2	53.2	70.2
Male	87	48	39	16	70	27	59	36	50
%	35.5	32.4	40.2	33.3	35.5	33.7	35.8	46.8	29.8
Total	245	148	97	48	197	80	165	77	168
Total %	100	60.4	39.6	19.6	80.4	32.7	67.3	31.4	68.6
Total per dimension		245		245		245		245	

From the total number of 245 learners, 158 of them representing 64.5% are identified as females, while 87 (35.5%) are identified as males. Under the processing learning style dimension, there were 148 (60.4%) respondents categorised as active learners and 97 (39.4%) learners were classified as reflective learners. Out of the 148 learners who were categorised as active learners, 100 (67.6%) learners are females, while 48 (32.4%) are males.

There were 97 learners who were categorised as reflective learners. Out of this number, 58 (66.7%) are females and 39 (40.2%) are males.

Under the perception learning style dimension, there were 48 (19.6%) respondents who were categorised as intuitive learners and 197 (80.4%) respondents were categorised as sensory learners. Out of the 48 learners who were classified as intuitive learners, 32 (66.7%) are females while 16 (33.3%) are males. Of the 197 learners who were categorised as sensory learners, 127 (64.5%) are females and 70 (35.5%) are males.

Under the input learning style dimension, there were 80 (32.7%) respondents who were categorised as verbal learners and 165 (67.3%) respondents who were categorised as sensory learners. Out of the 80 learners who were categorised as verbal learners, 53 (66.3%) are females while 27 (33.7%) are males. From the 165 respondents who were categorised as visual learners, 106 (64.2%) are females while 59 (35.8%) are males.

Under the understanding learning style dimension, there were 77 (31.4%) respondents who were categorised as global learners and 168 (68.6%) respondents who were categorised as

sequential learners. Out of the 77 learners who were categorised as global learners, 41 (53.2%) are females while 36 (46.8%) are males. Of the 168 respondents who were categorised as sequential learners, 118 (70.2%) respondents are females while 50 (29.8%) are males.

The learning style preferences based on learners' gender is also depicted in a graph.

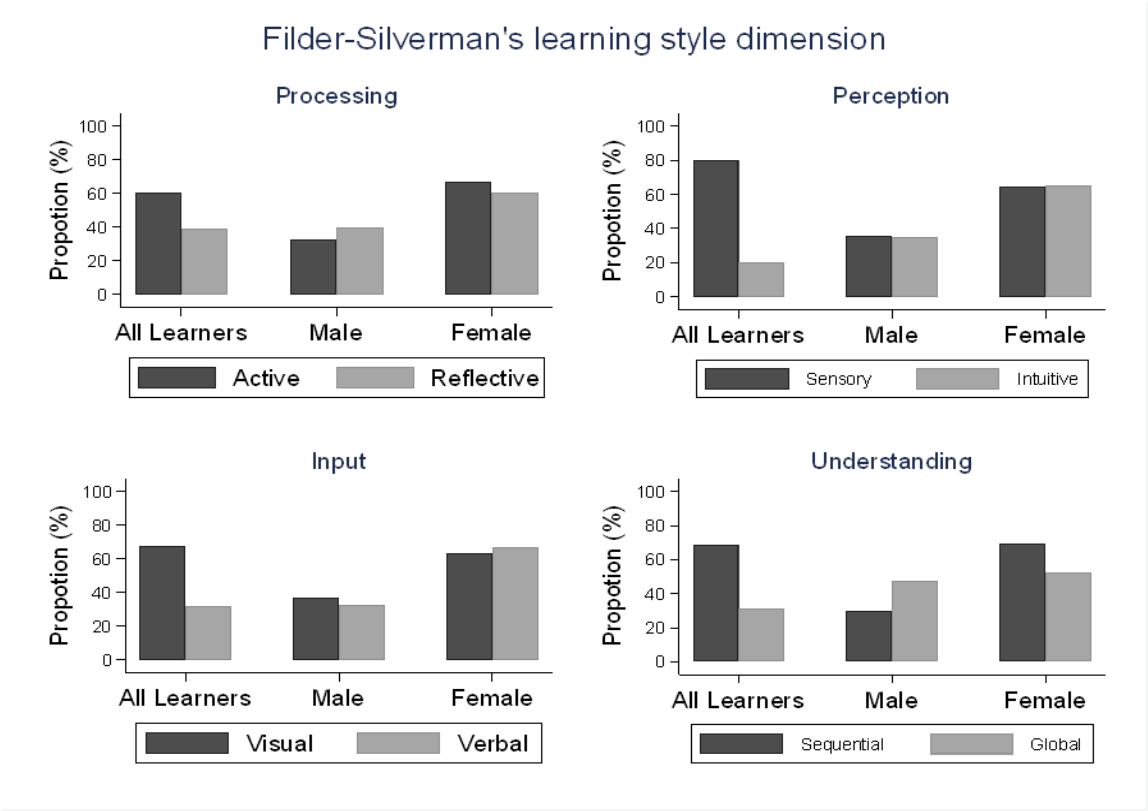


Figure 5.4: Proportion of learning style preferences by gender

From Figure 5.4, it is clear that a majority of the females have preferences for the active, sensory, verbal and sequential learning style dimensions, compared to males. However, from a general perspective, it can be inferred that, regardless of the gender differences, a majority of the physical sciences learners prefer to perceive information in both forms of active, sensing, visual and sequential learning style categories.

Potential differences between the learning styles of males and females across these schools

were assessed using a test of proportions. These are reported in Table 5.6. There were 158 females and 87 male respondents in each learning style category.

Table 5.6: Test of proportions of gender differences in learning styles

Learning style preferences	Male n (%)	Female n (%)	p-value
Active *processing*	49 (56.32)	100 (63.29)	0.2849
Reflective *processing*	38 (43.68)	58 (36.71)	0.2849
Sensory *perception*	70 (80.46)	126 (79.75)	0.8938
Intuitive *perception*	17 (19.54)	32 (20.25)	0.8938
Visual *input*	61 (70.11)	105 (66.46)	0.5576
Verbal *input*	26 (29.89)	53 (33.54)	0.5576
Sequential *understanding*	51 (58.62)	118 (74.68)	0.0093*
Global *understanding*	36 (41.38)	40 (25.32)	0.0093*

From Table 5.6, it can be concluded that the differences between males and females are not statistically significant in the realm of active-reflective, sensing-intuitive and visual-verbal learning styles. Statistically significant differences were observed for the sequential and global learning styles.

5.1.3 Results from the PSAT questionnaire

To explore aspects of the fourth research question of the study, "what impact, if any, does learning style-based instructions have on academic achievement?" the relationship between learning style-based instructions and learner academic achievement was investigated. In order to answer the above research question, the following null hypotheses were formulated and tested at significant levels:

Null hypothesis (H_o) 1: there is no significant difference between the mean pre-test and post-test scores for grade 11 learners in the control group.

Null hypothesis (H_o) 2: there is no significant difference between the mean pre-test and post-test scores for grade 11 learners in the experimental group.

Null hypothesis (H_o) 3: there is no significant difference between the mean post-test scores for learners in the control and the experimental group after controlling the effect of pre-test scores.

As already discussed (see section 3.8), in all the five schools, the pre-test was administered at the beginning of term three to seek learners' prior knowledge on the topic electricity and magnetism. This was followed by the intervention which lasted for five weeks. The post-test was conducted immediately after the intervention. In all the schools, the post-test was administered as part of their monthly test by their teachers to help learners feel that they were engaged in the test mood. Therefore learners at all the schools had taken the test being in the test mood.

The results from both the pre-test and the post-test were analysed using statistical tools as discussed in section 3.9. The scores for the two tests (Appendix L) were captured into the STATA version 15 and were used to compute the mean, the standard deviation and the t-test that helped the researcher to determine the level of significance of the different performances of the two groups of learners. The researcher further used the mean scores of the two tests within each group to compare the performance of the learners from the pre-test to the post-test and correlate it with their learning style preferences.

5.1.3.1 Results of PSAT pre-test

A pre-test was conducted before the treatment to establish whether the learners in the five schools were of the same ability or were comparable in terms of the topic electricity and magnetism before the treatment started. Table 5.7 illustrates descriptive statistics, such as mean, standard deviations and skewness of the pre-test scores which were calculated to identify the nature of distribution of data of the respondents from the five schools.

Table 5.7: Descriptive statistics of the pre-test scores on achievement for the total sample

School	Number of learners	Mean (SD)	Median (IQR)	Skewness
School A	58	31.31 (5.23)	32 (28-36)	-0.73
School B	55	31.75 (8.62)	30 (26-38)	1.14
School C	54	32.19 (10.94)	31 (24-40)	0.16
School D	38	32.95 (8.46)	31 (28-38)	0.17
School E	40	31.75 (5.44)	32 (29-36)	-0.43

The Table 5.7 illustrations that the mean, median and IQR of pre-test scores for the total sample are almost the same. The mean and standard deviation of the scores indicates that the

scores are not much dispersed from the central value. The distributions are positively skewed for the total sample. This shows that the scores are massed at the low end of the distribution in all the cases. The result of the pre-test scores is also presented graphically.

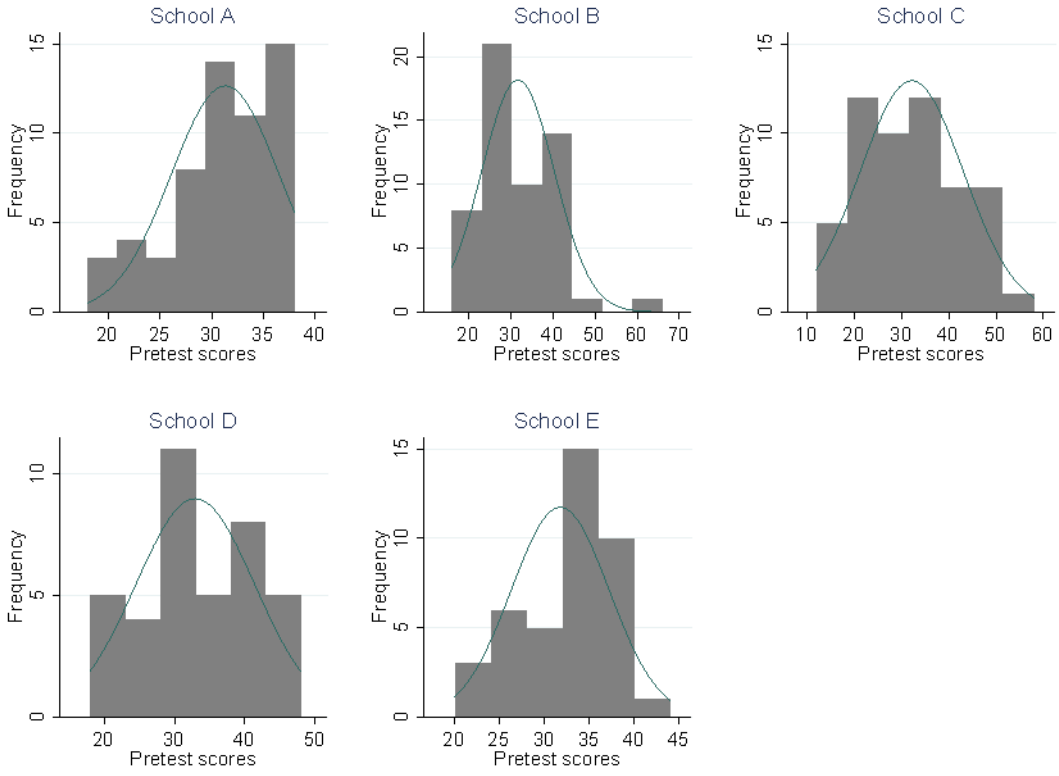


Figure 5.5: Histograms of pre-test scores by school

Table 5.7 and Figure 5.5 show the results of the pre-test scores for each sampled school. A pre-test was conducted before the treatment to establish whether or not the learners in the five schools were of the same ability or were comparable in terms of the topic electricity and magnetism before the treatment started.

Comparison of pre-test scores of learners in all schools

The researcher compared the pre-test scores of learners in all school in their achievement in electricity and magnetism for the total sample. The data and results of analysis are presented in Table 5.8.

Table 5.8: Comparison of pre-test scores in all schools

school	Obs	Rank Sum
School A	58	7010.50
School B	55	6511.00
School C	54	6646.50
School D	38	4972.50
School E	40	4994.50
Chi square:	0.780	
df	4	
p-value	0.9410	

The Kruskal Wallis test was conducted to determine if pre-test scores were different among the five schools. The test showed that there was no statistically significant difference in the pre-test scores among the schools.

Comparison of pre-test scores of learners in the experimental and control groups

Descriptive statistics, such as the mean (M), median, Mode, skewness and standard deviation (SD) of the PSAT pre-test scores, were calculated for the experimental and control groups to identify the nature of distribution of data. The statistical values of the pre-test scores of the experimental and control groups for the total sample and relevant sub-samples is presented below.

Table 5.9: Descriptive statistics for pre-test scores on total achievement in physical science for the experimental and control groups

School	Number of learners	Mean (SD)	Median (IQR)	Skewness
Experimental	205	31.96 (8.47)	32 (26-38)	0.44
Control	40	31.75 (5.44)	32 (29-36)	-0.43

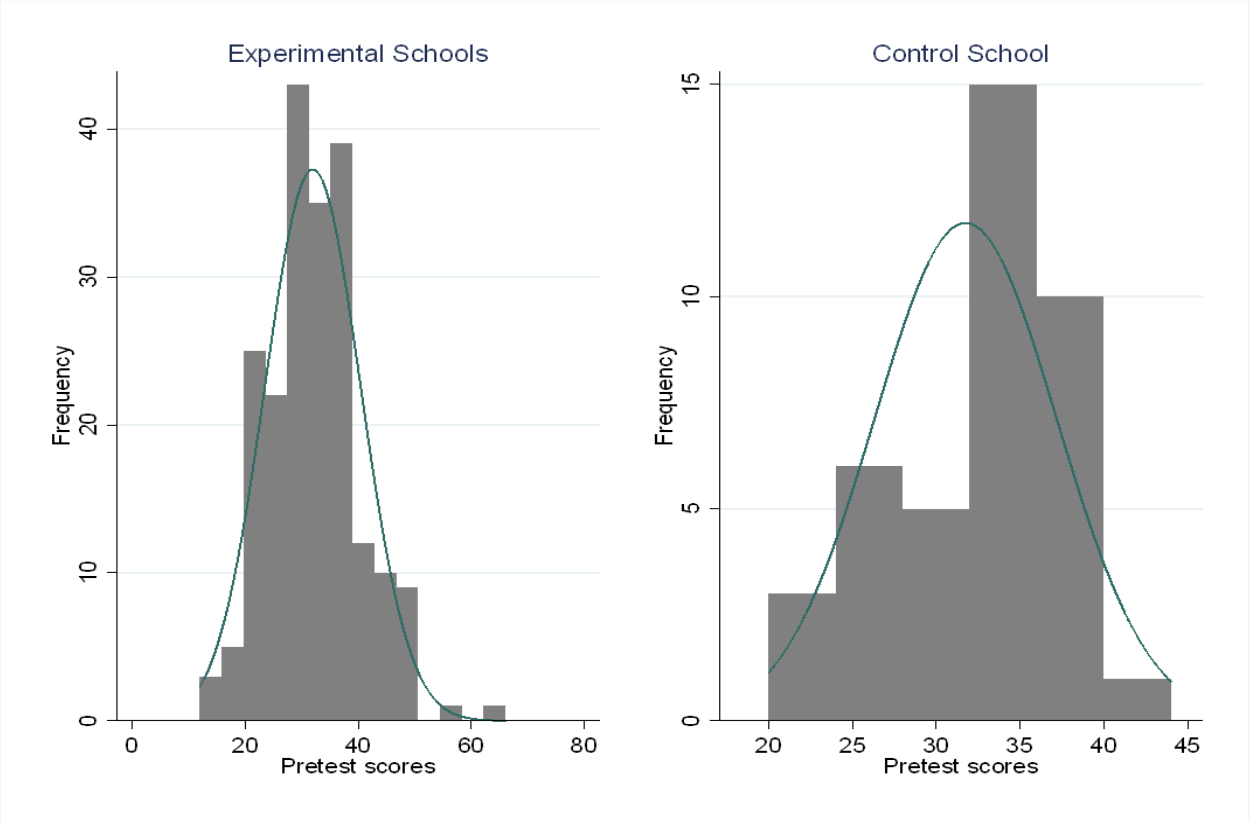


Figure 5.6: Histograms of pre-test scores by the experimental group and the control group

From Table 5.9, it can be seen that the mean, median and mode of the pre-test scores for the total sample and the sub-samples are almost the same. The standard deviation and the IQR of the scores indicate that the scores are not much dispersed from the central value. The distributions are positively skewed for the total sample. This shows that the scores are massed at the low end of the distribution in all the cases.

As Figure 5.6 above shows, the scores are mainly concentrated between 20 and 45 indicating a greatly distributed set of scores indicated by the SD.

Comparison of pre-test scores in the experimental group

A further test of significance of the difference between the means of pre-test scores on achievement in electricity and magnetism for the experimental group was conducted.

Table 5.10: Comparison of pre-test scores in the experimental schools

school	Obs	Rank Sum
School A	58	5895.00
School B	55	5477.00
School C	54	5576.50
School D	38	4166.50
Chi square:	0.696	
df	3	
p-value	0.8742	

A Kruskal Wallis test was conducted to determine if pre-test scores were different for the four (4) schools sampled for the experimental group. As Table 5.10 shows, the values of Chi-Square (0.696) obtained for the four schools sampled for the experimental group for the total sample with df 3 are not significant. The test showed that there was no statistical difference in the pre-test scores of the four schools prior to experimentation.

Results from the PSAT post-test

In this section, results are considered for learners' scores on the post-test. This was done to evaluate the impact of the intervention on the experimental group in order to understand the effectiveness of the learning style-based instructions on learner achievement and compare the results of the intervention to the control group. The major findings from the PSAT post-test for all schools are summarised in Table 5.11 and Figure 5.7.

Table 5.11: Descriptive statistics of the pre-test scores on achievement for the total sample

School	Number of learners	Mean (SD)	Median (IQR)	Skewness
School A	58	66.97 (11.23)	67 (60-76)	-0.55
School B	55	62.15 (10.69)	64 (56-68)	-0.09
School C	54	63.11 (9.55)	64 (58-68)	-0.32
School D	38	64.53 (11.65)	66 (56-74)	-0.23
School E	40	37.70 (7.88)	37 (32-42)	0.53

The statistical measures, namely, mean, median, standard deviation and skewness were computed on the post-test achievement scores on electricity and magnetism for the total sample.

The arithmetic mean and median of the post-test scores for the total sample do not vary much. The standard deviation and IQR of the scores indicate that the scores are not much dispersed from the central value. The distributions are negatively skewed for the total sample except for the control group in total.

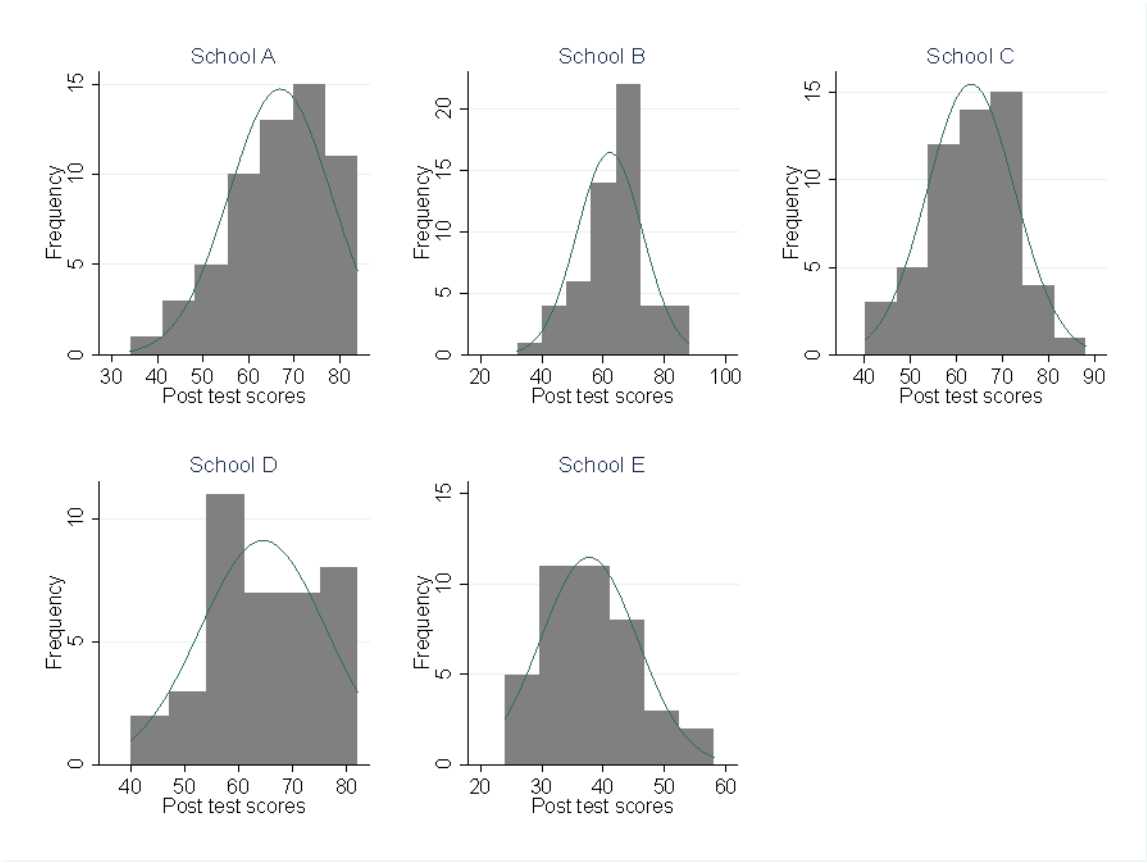


Figure 5.7: Histograms of post-test scores by school categories

Comparison of post-test scores of learners in the experimental and control groups with regards to their achievement in electricity and magnetism

Comparison was made on the post-test scores of learners in the experimental and control groups with regards to their achievement in electricity and magnetism for the total sample. The mean and standard deviation of the post-test scores of learners were calculated and is subjected to a test of significance of difference between means. The data and the results of analysis are presented in Table 5.12

Table 5.12: Comparison of post-test scores of learners in the experimental and control groups

School	Number of learners	Mean (SD)	Median (IQR)	Skewness
Experimental	205	64.20 (10.83)	64 (58-72)	-0.26
Control	40	37.70 (7.88)	37 (32-42)	0.53

The statistical measures, namely, mean, median, mode, standard deviation and skewness were computed on the post-test achievement scores on electricity and magnetism for the experimental group and the control group for the total sample. Table 5.12 above shows the results. The mean and median of the post-test scores for the total sample show much difference. Standard Deviation and the IQR of the scores indicate that the scores are much dispersed from the central value. The distributions are positively skewed for the total sample.

The mean values obtained for the total sample given in Table 5.12 makes it clear that the learning style-based instructions are more effective than the traditional teaching method with regards to gaining in achievement in electricity and magnetism for the total sample.

The comparison of achievement in electricity and magnetism of experimental and control groups in post-test scores are depicted in a graph.

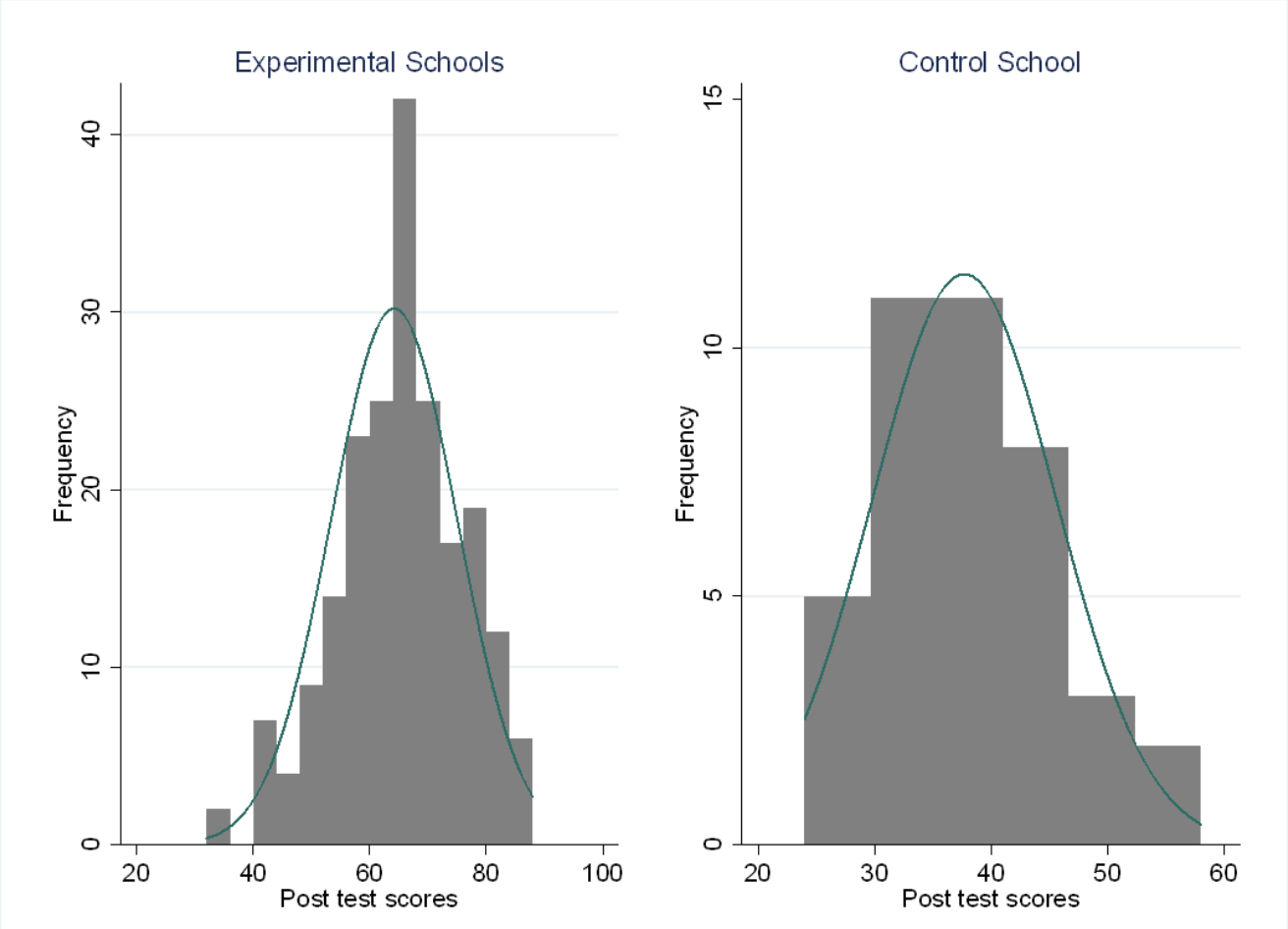


Figure 5.8: Achievement in electricity and magnetism of experimental and control groups for the total sample

The graphical representation indicates that the experimental group and the control group vary in the post-test scores of the gain scores. It is clear from Figure 5.4 that, after implementing learning style-based instructions with the experimental group and the traditional instruction with the control group, the experimental group performed well in the post-test scores. Thus, it is concluded tentatively that, in attaining achievement in electricity and magnetism at secondary school level, the learning style-based instructional strategies are more effective than the traditional teaching strategy.

Comparison of post-test scores on achievement in electricity and magnetism of experimental and control groups using Analysis of Variance

Table 5.13: ANOVA results on post-test in all schools

Source	SS	df	MS	F	p-value
Between groups	24256.3521	4	6064.0880	56.80	<0.001
Within groups	25623.9744	240	106.76656		
Total	49880.3265	244	204.427568		

The analysis of the variance was used to determine whether both groups were comparable after the intervention. A significant difference was found between pre and post-test scores at p<0.05 level for the two groups [F (4,240)=56.80, p=<0.001], since the p-value is <0.001, which is below 0.05, and therefore, there is a statistically significant difference in the mean post-test scores between the five schools.

Comparison of the post-test and pre-test scores on achievement in electricity and magnetism

Paired t-test of the post-test

Control Group

To evaluate the impact of the intervention on the control group achievement in electricity and magnetism, descriptive statistics were calculated for their pre-test and post-test scores on PSAT.

Table 5.14: Descriptive statistics for control group

Achievement scores	Mean	N	Standard deviation
Pre-test	31.75	40	5.44
Post-test	37.70	40	7.88

Table 5.14 shows the descriptive statistics for the control group. To evaluate the impact of the intervention on the control group achievement on the topic of electricity and magnetism, descriptive statistics were calculated for their pre-test and post-test on PSAT. A paired sample t-test was conducted to examine whether there was a significant difference between the mean pre-test and post-test scores for the control group. The control group performed well in the post-test (M=37.70, SD=7.88) compared with the pre-test (M=31.75, SD=5.44) with a significant difference between the pre-test and post-test scores in the control group, which can be reported as t (39) = 3.8931, $p< 0.05$ (see Table 5.15).

Table 5.15: Paired sample t-test for the control group

	Paired differences						
	95% confidence interval of the difference						
	Mean difference	SD	Lower	Upper	t	df	significance(two-tailed)
Pre-post t-test	5.95	9.67	2.86	9.04	-3.8931	39	<0.0004

The results in Table 5.15 therefore validate the rejection of the null hypothesis ($H_0$1), which states that there is no significant difference between the mean pre-test scores and post-test scores for learners in the control group.

Experimental Group

To evaluate the impact of the intervention on the experimental group's achievement in electricity and magnetism, descriptive statistics were calculated for their pre-test and post-test scores.

Table 5.16: Descriptive statistics for the experimental group

Achievement scores	Mean	N	Standard deviation
Pre-test	31.96	205	8.47
Post-test	64.20	205	10.83

To evaluate the impact of the intervention on the experimental group achievement in the subject of electricity and magnetism, descriptive statistics were calculated for their pre-test and post-test scores on PSAT. The results of the analysis show that there was a statistical difference between the mean pre-test and post-test scores for the experimental group. The experimental group performed well in the post-test (M=64.20, SD=10.83) compared with the pre-test (M=31.96, SD=8.47) with a significant difference between the pre-test and post-test scores, which can be reported as t(204)=-41.083, p< 0.05 (see Table 5.17). The above results validate the rejection of the null hypothesis ($H_0$1): There is no significant difference between the mean pre-test and post-test scores for learners in the experimental group.

Table 5.17: Paired sample t-test for the experimental group

	Paired differences						
	95% confidence interval of the difference						
	Mean difference	SD	Lower	Upper	t	df	significance(two -tailed)
Pre-post t-test	32.24	11.24	30.69	33.79	-41.0836	204	<0.0001

Table 5.18: Descriptive statistics of achievement scores by the experimental and control groups

		Pre-test		Post-test	
Group	N	Mean	Standard deviation	Mean	Standard deviation
Control group	40	31.75	5.44	37.70	8.47
Experimental group	205	31.96	8.47	64.20	10.83

The above results validate the rejection of the null hypothesis ($H_0$3): There is no significant difference between the mean pre-test and post-test scores for learners in the experimental

group and the control group.

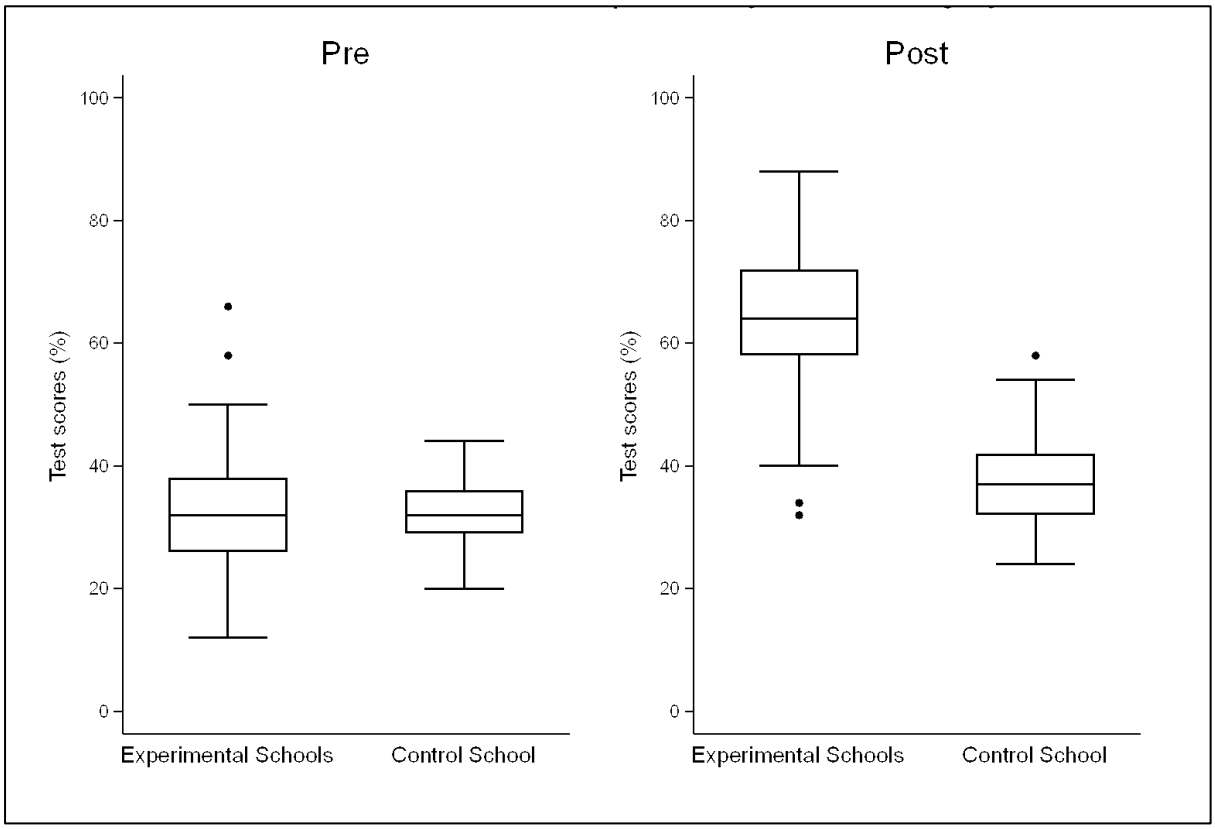


Figure 5.9: Box plots of pre-test and post-test scores for the control and experimental groups

Figure 5.9 above presents a box and whiskers plot to compare the means of scores obtained by learners in the pre-test and the post-test for the experimental and control groups. The median value is represented by the heavy solid black line in each box. The boxes indicate the interquartile range (IR). Whiskers extend out from both ends of the boxes. The box and whisker graphs in the pre-test scores overlap. However, the statistics (median, upper quartile and lower quartile) for the control group are lower than the experimental group in the post-test scores. The control group graph is clustered between the median and the lower quartile. The experimental group interquartile is more spread than the control group interquartile range. Overall, it appears that the control group earned a lower score than the experimental group.

Consequently, a test of significance of difference between the means of pre-test scores and post-test scores on achievement in physical sciences for the total sample was done to compare the pre-test scores and the post-test scores of the total sample by testing the following hypothesis:

Null Hypothesis (H_o3): There is no significant difference between the mean post-test scores for learners in the control and the experimental group after controlling the effect of pre-test scores.

Table 5.19: Paired-sample t-test for pre- and post-test scores for the experimental and the control groups

	t- statistic	Mean diffence	Standard Deviation	95% Confidence interval of the difference	df	p-value
Experimental	-41.0836	32.24	11.24	30.69 -33.79	204	<0.0001
Control	-3.8931	5.95	9.67	2.86 - 9.04	39	0.0004

A paired-sample t-test was conducted to examine whether there was a significant difference between the mean pre-test and post-test scores for the experimental and the control groups. The experimental group surpass the control group in the post-test (M=32.24, SD=11.24). Table 5.19 shows that there is a significant difference between post-test scores in the experimental group which can be reported as t (204) = -41.0836, p< 0.0001.

The obtained p-value is significant at 0.05% therefore we reject the null hypothesis. This shows that there was a significant improvement in the marks of the learners in the experimental group after the intervention programme. This reveals that there exists significant difference in the means of post-test scores and pre-test scores on achievement in electricity and magnetism for the total sample. There is thus strong evidence (t=-41.089, p-value=<0.0001) that the intervention programme improved the marks obtained by the learners in the experimental group. In this study, the intervention programme improved the results, on average, by 31 marks.

From the confidence interval value, the researcher is 95% confident that the mean difference in the marks obtained by the learners before and after the intervention programme is between 29.97911 and 33.00129. Based on this 95% confidence interval, we can conclude that there is a statistically significant difference in the marks obtained by the learners after the intervention programme was introduced since the confidence interval for the mean difference does not

include zero.

The above results validate the rejection of the null hypothesis ($H_0$3): There is no significant difference between the mean post-test of learners in the experimental group and the control group.

Analysis of covariance

Analysis of genuineness of the difference in achievement in the post-test of experimental and control groups

The sample selected for the present study was made up of intact classroom groups from different institutions; there was a slight difference in the means of the pre-test scores. Even though it was not significant, it is difficult to ascertain whether the difference between the pre-test and post-test scores is a result of the experimental treatment or other variables. Thus, the researcher cannot conclusively say that these groups differed significantly by merely comparing the control group' and the experimental group post-test scores. So it becomes necessary to analyse the scores using the Analysis of Co-Variance (ANCOVA). Using ANCOVA, differences in the pre-test scores were controlled.

ANCOVA is commonly used when there is a pre-test/post-test design, where a test is given before participants are allocated to the experimental condition and then the same test is given after the experimental condition. Here, the pre-test scores are used as covariate.

In this case, the effects of pre-test and other relevant variables are partialled out and the results adjusted. Means of the post-test scores were compared. The use of the statistical technique, ANCOVA, is thus justified for the analysis of the present study. The scores obtained in an achievement test employed as pre-test and post-test were subjected to ANCOVA to determine the success of the learning style-based instructions over the traditional teaching strategies.

Table 5.20: ANCOVA-ANOVA of post-tests while controlling for pre-test scores

Source	Partial SS	df	MS	F	p-value
Model	26905.753	5	5381.1505	55.98	<0.0001
school	24180.259	4	6045.0647	62.89	<0.0001
Pre	2649.4006	1	2649.4006	27.56	<0.0001
Residual	22974.574	239	96.127924		
Total	49880.327	244	204.42757		

In all statistical tests, alpha (α) level of 0.05 was employed.

The result of the ANCOVA shows that a significant effect of the covariate, which is the pre-test as F (1, 244) = 27.56, $p < 0.05$. It also yielded a significant effect on the instructional group as F (4, 244) = 62.89, $p < 0.05$. Since the ANCOVA results showed that there were statistically significant post-test scores between the groups, the null hypothesis ($H_0$3) was rejected. Thus the learning style-based instruction reveals significant difference in the post-test scores on learner achievement in electricity and magnetism of the experimental and control groups after the intervention.

5.2 Learning style preferences and academic achievement of learners

This section presents the results of average scores obtained by learners in the experimental group who had a preference for a category of a learning style dimension. The section also describes the learners' academic achievement scores within each learning style dimension statistically using means, standard deviations and variances and estimated region for the location of the true mean at 95% confidence interval mean and presented in the sections that follow. This comparison was examined by tracking the average marks of learners in the pre-test and post-test and comparing these average marks to their preferred learning style categories.

The first part of this analysis examined the minimum, arithmetic mean and maximum values. In statistics, the sample maximum and sample minimum, also called the largest observation and smallest observation, are the values of the greatest and least scores of a sample. Thus, in this study, the minimum and maximum score for each learning style category are presented.

To calculate the arithmetic mean of this set of data, the researcher added up all of the data values (x) and then divided the result by the number of values (n) for each learning style category.

Table 5.21: Summary of average score for pre-test and post-test for each learning style category

Learning style dimension	Pre Test			Post Test		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Active	12	33	58	32	63	88
Reflective	12	33	66	40	65	88
Intuitive	22	32	50	44	64	84
Sensory	12	33	66	32	64	88
Verbal	12	34	66	32	66	88
Visual	16	32	58	34	63	88
Global	12	33	48	34	64	88
Sequential	12	33	66	32	64	88

From the Table 5.21, the minimum, arithmetic mean, and the maximum values for the pre-test and post-test scores, based on the learning style categories for the total sample, vary significantly. The means of the scores in the pre-test and the post-test scores indicate that the scores are much dispersed from the central value, with learners achieving higher scores in the post-test. The mean scores for each learning style category also improved significantly in the post-test scores, although there were slight differences in the mean scores.

The scores were further scrutinised using standard deviation and variances. This is presented in Table 5.22.

Table 5.22: Comparison of academic achievement in electricity and magnetism based on the learning styles of the grade 11 physical sciences learners

Learner's learning style dimensions		Number of learners	Achievement means for each learning style dimension			Standard deviation and variance		Skewness
			95% confidence interval for mean					
			Lower bound	Upper bound	Mean	SD	Variance	
Processing	Active	127	61.66	65.27	63.5	10.27	105.55	-0.39
	Reflective	78	62.78	68.04	65.4	11.66	135.91	-0.18
Perception	Sensing	172	62.52	65.90	64.2	11.22	125.85	-0.29
	Intuitive	33	61.09	67.27	64.2	8.71	75.84	0.14
Input	Visual	140	61.56	65.06	63.3	10.46	109.74	-0.27
	Verbal	65	63.29	68.95	66.1	11.42	130.36	-0.32
Understanding	Sequential	144	62.36	65.83	64.1	10.53	110.84	-0.25
	Global	61	61.48	67.43	64.5	11.61	134.85	-0.27

The Table 5.22 shows that the mean for academic achievement scores of grade 11 active/reflective learners were 63.5 and 65.4 respectively. The table also shows that at 95% confidence interval, the lower and upper bound for the true mean of academic achievement was 61.66 and 65.27 for active learners and 62.78 and 68.04 for reflective learners. This suggests that the probability of finding the location of the true score at 95% confidence interval for both active and reflective learners was within a similar region of distribution of their academic achievement scores. Furthermore, the table shows that the measure of standard deviation for the spread of academic achievement scores for active learners was 10.27 and, for reflective learners, it was 11.66. This measure of standard deviation indicates that the distribution of scores was nearly the same for both active and reflective learners.

Similarly, the mean for academic achievement scores of sensing learners was 64.2 and of intuitive learners were 64.2 at 95% confidence interval. The lower and upper bound of the true mean of measures of academic achievement score was 62.52 and 65.90 for sensing

learners, and 61.56 and 65.06 for intuitive learners and the measure of standard deviation for the distribution of academic achievement scores was 11.22 for sensing learners and 8.71 for intuitive learners. This further suggests that the distribution of academic achievement scores of sensing learners was relatively more dispersed than academic achievement scores of intuitive learners, but the difference was negligible.

The mean of academic achievement scores was 63.3 for visual learners and 66.1 for verbal learners. In addition, the table shows that, at 95% confidence interval, the lower and upper bound for the true mean of academic achievement scores of visual learners was 61.56 and 65.06 respectively and verbal learners was 63.29 and 68.95. This means that the probability of finding the location of the true score at 95% confidence interval for both visual and verbal learners was almost within the same region of distribution of scores. Moreover, Table 5.9 also shows that the measures of standard deviation about the distribution of academic achievement scores were 10.46 for visual learners and 11.42 for verbal learners. This demonstrates that the distribution of academic achievement for both visual and verbal learners was comparable.

The mean of academic achievement scores was 64.1 for sequential learners and 64.5 for global learners. In addition, at 95% confidence interval, the lower and upper bound for the true mean of academic achievement scores of sequential learners was 62.36 and 65.83, and global learners was 61.48.29 and 67.43. This means that the probability of finding the location of the true score at 95% confidence interval for both sequential and global learners was almost within same region of distribution of scores. Moreover, the result shows that the measures of standard deviation about the distribution of academic achievement scores were 10.53 for sequential learners and 11.61 for global learners. This demonstrates that the distribution of academic achievement for both sequential and global learners was approximately comparable.

The reflective (mean=65.4), intuitive (mean=64.2), verbal (mean=66.1) and global (mean=64.1) have better achievement scores in electricity and magnetism. Garner-O'Neale and Brooks (2013) suggested that learning style preferences associated with physical science learners, active, sensing, visual and sequential, would have higher achievement scores in electricity and magnetism. This is because a majority of learners have these learning styles in the science classroom. Reflective learners performed better than active learners. Although the differences are not statistically significant, Felder's (1993) observation that engineering

instruction favours those students who are reflective, intuitive, verbal and sequential is borne out in the results. This shows that the majority of the learners sampled learn by thinking things through.

The intuitive learners achieved higher scores than the sensing learners even though sensing learners tend to pay more attention to details. However, topics in electricity and magnetism involve theories and concepts to be learnt which might have been more appealing to the intuitive learners than the sensing learners.

The verbal learners achieved higher scores, on average, than the visual learners. This is not surprising since it was indicated earlier in the background section that most Mthatha science teachers still use the lecture method in their science classrooms to teach most concepts in sciences that would rather make descriptions in writing.

In addition, the global learners achieved higher scores on average than sequential learners. Global learners assimilate information by first "seeing the big picture", in this case, perceiving the concept of electromagnetic induction and then they go back to discover the details. This can be advantageous.

5.3 The relationship between learning style preferences and academic achievement

In order to investigate the relationship between learning style preferences and academic achievement among the respondents, the Pearson Moment Correlation Coefficient was used. The Pearson Moment Correlation Coefficient is an appropriate tool for testing association. The statistics that show the correlation coefficients and significance tests that measure the correlation between Felder-Silverman learning style preferences and academic achievement among grade 11 physical science learners is summarised and presented in Table 5.23 below.

Table 5.23: Correlation coefficients between learning style preferences and academic achievement of learners

Correlations*						
		Academic Achievement	Active/ Reflective	Sensing/ Intuitive	Visual/ Verbal	Sequential/ Global
Academic Achievement	Pearson Correlation	1	.087	-.001	.121	.015
	Sig. (2-tailed)		.213	.989	.084	.828
	N	205	205	205	205	205
Active/Reflective	Pearson Correlation	.087	1	.094	.092	-.049
	Sig. (2-tailed)	.213		.179	.189	.489
	N	205	205	205	205	205
Sensing/Intuitive	Pearson Correlation	-.001	.094	1	.101	-.053
	Sig. (2-tailed)	.989	.179		.150	.452
	N	205	205	205	205	205
Visual/Verbal	Pearson Correlation	.121	.092	.101	1	-.008
	Sig. (2-tailed)	.084	.189	.150		.911
	N	205	205	205	205	205
Sequential/Global	Pearson Correlation	.015	-.049	-.053	-.008	1
	Sig. (2-tailed)	.828	.489	.452	.911	
	N	205	205	205	205	205

*correlation is significant at the 0.05 level (2-tailed)

According to Table 5.23 above, a general low correlation was reported among all the learning style categories. Table 5.23 shows that the only learning style that gets closer to the significant level is the visual/verbal learning style and its association to academic achievement. However, the correlation coefficients for the relationship between visual/verbal and academic achievement (r_3=0.121, n=205, p=0.084) was below 0.3. Tabachnick and Fidell (2001) suggest that a variable should have correlation between 0.3 and 0.7 for it to be significant. In addition, the table presents that at α=0.05, none of the independent variables were statistically significantly related to academic achievement in electricity and magnetism.

Table 5.23 also shows that none of the associations among the learning style dimensions were greater than 0.2. This shows that low associations were observed among the learning style dimensions in the correlations table. Based on the result, there was no statistical significant correlation between the academic achievement and the learning style preferences of the learners.

On the whole, the means, confidence intervals, standard deviations, variances and measures

of correlation in this study showed that there was very little systematic variation in academic achievements in electricity and magnetism in relation to learning style preferences. Hence, the data were disaggregated to the academic achievement levels (high and low achievers), and from the gender perspective. A one-way analysis of variance (ANOVA) was carried out to investigate the existence of possible differences among learning style categories and academic achievements. Furthermore, multiple regression analysis was conducted to determine the amount of variation in academic achievement in electricity and magnetism in relation to learning style preferences among the grade 11 learners.

We begin with how academic achievement of learners is linked to the learning style preferences by considering the learning style profiles of learners who achieved 80% and above, and learners achieving below 40% in the post-test and having different learning style profiles.

Table 5.24: Learning style profiles and academic achievement of top achievers and low achievers

Learning style profiles	Number of top achievers	Percentage %	Number of low achievers	Percentage %
Active+Sensing+Visual+Sequential	2	11.1	0	0
Active+Sensing+Visual+Global	1	5.6	1	50
Active+Sensing+Verbal+Global	1	5.6	0	0
Active+Sensing+Verbal+Sequential	2	11.1	1	50
Reflective+Sensing+Verbal+Sequential	4	22.2	0	0
Reflective+Sensing+Verbal+Global	2	11.1	0	0
Reflective+Sensing+Visual+Sequential	2	11.1	0	0
Reflective+Sensing+Visual+Global	2	11.1	0	0
Reflective+Intuitive+Verbal+Global	1	5.6	0	0
Reflective+Intuitive+Verbal+Sequential	1	5.6	0	0
Total	18	100	2	100

Results from Table 5.24 show that even though learners may have the same learning style profiles, their academic achievements may not be the same. From Table 5.24, it is clear that some learners had the same learning style profiles but achieved high marks and others achieved low marks. This implies that having the same learning style profiles does not mean the academic achievement may be the same in electricity and magnetism. Thus, being active or reflective, sensing or intuitive, visual or verbal and sequential or global does not guarantee good results as some active or reflective, sensing or intuitive, visual or verbal and sequential or global learners obtained poor results.

5.3.1: Correlations between learning style preferences and high achievers

The data were disaggregated by the academic achievement levels. This is presented in Table 5.25

Table 5.25: Correlations between learning style preferences and high achievers

Correlations		
		Overall
Processing	Pearson correlation	-0.073
	Sig (2-tailed)	0.528
	N	78
Perception	Pearson correlation	-0.019
	Sig (2-tailed)	0.919
	N	33
Input	Pearson correlation	-0.167
	Sig (2-tailed)	0.185
	N	65
Understanding	Pearson correlation	-0.038
	Sig (2-tailed)	0.773
	N	61

Table 5.25 shows no correlation between learning style preferences and academic achievement of learners in the high achievers group. The only one learning style that gets close to the significant level is between the input (visual/verbal) learning style dimension and academic achievement ($r=-0.167$, $p>0.05$, $n=65$). None of the other learning styles and their association with academic achievement among high achievers was statistically significant. Thus, there is generally no correlation between the various learning styles and academic achievement scores, with the weakest correlation being 0.019 for the sensing-intuitive learning style category.

5.3.2 Comparison of learning style categories and academic achievement

A one-way analysis of variance (ANOVA) was conducted to investigate the existence of possible differences among learning style categories and academic achievements, as well as by gender. To determine whether any of the differences between the means are statistically significant, a comparison between the p-value and the significance level was done to assess the null hypothesis (H_o3), which states that the sampled population means are all equal and that there is no significant difference between learners' academic achievement scores after the

intervention and their learning style preferences, as well as their gender.

Table 5.26: Summary of Analysis of Variance (one-way ANOVA)

		Sum of Squares	df	Mean Squares	F	Sig.
Active/Reflective	Between groups	182.933	1	182.933	1.563	0.213
	Within groups	23764.462	203	117.066		
	Total	23947.395	204			
Sensory/Intuitive	Between groups	0.021	1	0.021	0.000	0.989
	Within groups	23947.374	203	117.967		
	Total	23947.395	204			
Visual/Verbal	Between groups	350.208	1	350.208	3.013	0.084
	Within groups	23597.187	203	116.242		
	Total	23947.395	204			
Sequential/Global	Between groups	5.609	1	5.609	0.048	0.828
	Within groups	23941.786	203	117.940		
	Total	23947.395	204			
Gender	Between groups	180.216	1	180.216	1.539	0.216
	Within groups	23767.179	203	117.080		
	Total	23947.395	204			

Table 5.26 shows the analysis of one-way ANOVA between learning style preferences among the learners and academic achievement as well as between gender and academic achievement variables. Results showed that there was no difference in academic achievement between active and reflective learning style preferences at $p<0.05$ level ($F(1, 203) = 1.563$, $p = 0.213$). The results also denote that there was no difference between academic achievement and sensory and intuitive $F(1, 203) = 0.000$, $p = 0.989$) learning styles. The visual/verbal learning style and academic achievement ($F(1, 203) = 3.013$, $p = 0.084$) did not show any difference in results.

In addition, Table 5.26 also shows that there was no significant effect of gender on academic achievement at $p<0.05$ level for $F(1, 203) = 1.539$, $p = 0.216$ for male and female. On the whole, both males and females have similar scores in the post test on electricity and magnetism.

5.3.3 Multiple regression analysis: Determining academic achievement in electricity and magnetism from Felder-Silverman learning style preferences

The quantitative data of the study were further subjected to the regression model fit test which has one dependent and four independent variables. Therefore, the indices of the coefficient of determination (R square) in Table 5.27 and ANOVA tests for R^2 of the regression model in Table 5.28 were used to empirically answer the fourth research question: What impact, if any, does the learning style preference of learners have on their academic achievements?

The regression model equation is presented as follows:

$$\text{Academic Performance} = \beta_0 + \beta_1 (\text{visual/verbal}) + \beta_2 (\text{sensing/intuitive}) + \beta_3 (\text{active/reflective}) + \beta_4 (\text{sequential/global}) + \epsilon,$$

Where:

- β_0 is the intercept – the mean of the academic performance when learning style dimension has no effect on academic performance, while
- β_1, β_2, β_3, and β_4 are standard coefficients of the predictor variables (learning style dimensions) and ϵ stands for an error term in the model.

An accurate estimate of standard coefficients β_1, β_2, β_3, and β_4 of the regression model indicates the relative importance of each dimension of learning styles in explaining academic achievement in electricity and magnetism. Before testing the regression model, assumptions, such as outliers, multicollinearity, homoscedasticity, linearity, normality and independence of residuals, were checked on the data in four different ways. These are: inspecting the Normal Probability Plot of the regression standardised residuals and the residual scatterplots. These outliers were requested as part of the regression analysis. Figures 5.10, 5.11, 5.12 and 5.13 illustrate how these assumptions were checked.

5.3.3.1: Test for the assumptions of multicollinearity among the predictor variables

Collinearity diagnostics was performed on the four variables that had significant correlation with the dependent variable as part of the multiple regression procedure. This was done to reveal problems with multicollinearity that may not be evident in the correlation matrix. The results are presented in Table 5.27.

Table 5.27 Collinearity statistics for grade 11 learners on relative contribution of learning styles on the level of academic achievement

Model	Unstandardised coefficients		Standardised coefficients	t	Sig.	95% Confidence interval for B		Collinearity statistics	
	B	Std. error	Beta (β)			Lower bound	Upper bound	Tolerance	VIF
1 (Constant)	58.291	4.320		13.494	0.00	49.772	66.809		
Active/Reflective	1.769	1.571	0.079	1.126	0.262	-1.329	4.867	0.982	1.018
Sensing/Intuitive	-0.561	2.078	-0.019	-0.270	0.787	-4.659	3.536	0.980	1.020
Visual/Verbal	2.687	1.639	0.116	1.639	0.103	-0.545	5.919	0.983	1.017
Sequential/Global	0.451	1.658	0.019	0.272	0.786	-2.818	3.719	0.995	1.005

a. Dependent variable: academic achievement

b. Independent variable: Learning style categories

In Table 5.27, two values for detecting mathematical multicollinearity are given: tolerance and its reciprocal, variance inflation factor (VIF). By definition, tolerance is an indicator of how much of the variability of the specified independent variables in the model is not explained by the other independent variables in the model. It is calculated using the formula $1\text{-}R^2$ for each variable (Belsley, Kuh, & Welsch, 1980). Pallant (2011) suggests that, if the tolerance value is less than 0.10, it shows that collinearity is possible.

Variance inflation factor (VIF) is the reciprocal of tolerance as $1/1 - R^2$). According to Chatterjee, Hadi and Price (2006), a VIF value greater than 10 signals a problem of multicollinearity but a value close to 1 signals orthogonality among the independent (predictor) variables. As shown on Table 5.27, the tolerance value for each independent variable is between 0.980 and 0.995 which is greater than 0.10. This attests that the multicollinearity assumption was not considered a disturbance that causes volatility in the data (Allison cited in Midi, Sarkar, & Rana, 2010). This is also supported by VIF values between 1,005 and 1.018 which are well below the cut-off value of 10. Generally, the confidence intervals of the coefficients tend to become narrow and the Pearson's correlation coefficient between these four independent variables with the dependent variable was low.

In conclusion, the collinearity test on the predictor variables showed that there was no sign of a multicollinearity problem among the independent (predictor) variables. The tolerance and VIF values for all the four learning style dimensions in Table 5.27 proved that there was no

sign of multicollinearity problems.

5.3.3.2 Test for the assumptions of normality of residuals (constant variance)

According to Leech, Barrett and Morgan (2005), to check the normality of the data, "[a] simpler guideline is that if the skewness is less than plus or minus one (< ±1.0), the variable is at least approximately normal". Therefore, the skewness test in the last column in Table 5.27 for grade 11 learners shows that the values of skewness for academic achievement in each learning style was well below the absolute value of 1. This indicates that the data on the dependent variable (academic achievement) were approximately normally distributed.

Cohen, Cohen, West and Aiken (2003) state that, if the assumptions of normality are violated, the significance tests are invalid and the residuals are randomly distributed if the residuals of the data are normally distributed. Therefore, the assumption of normality was checked by observing the normal probability plot of residuals. According to Leech et al. (2005), in the graphic display of scatterplot, "if the dots created a pattern, this would indicate the residuals are not normally distributed, the residual is correlated with the independent variables, and/or the variances of the residuals are not constant" (p. 102).

Freund, Wilson and Sa (2006) state that residuals' scatterplot of data points that do not violate assumptions of regression model is characterised by randomly the same distribution of points around the horizontal band or intercept (R^2=0). Freund et al. (2006) further state that, if the plots of residuals show up a recognisable systematic pattern or a funnel shape that faces towards the left (i.e. the occurrence of larger residuals with larger predicted values), it indicates the violations of assumptions of variations of common variance. In the light of this view, the scatterplot of standard residuals against predicted values of academic achievement of grade 11 learners is examined in Figure 5.11.

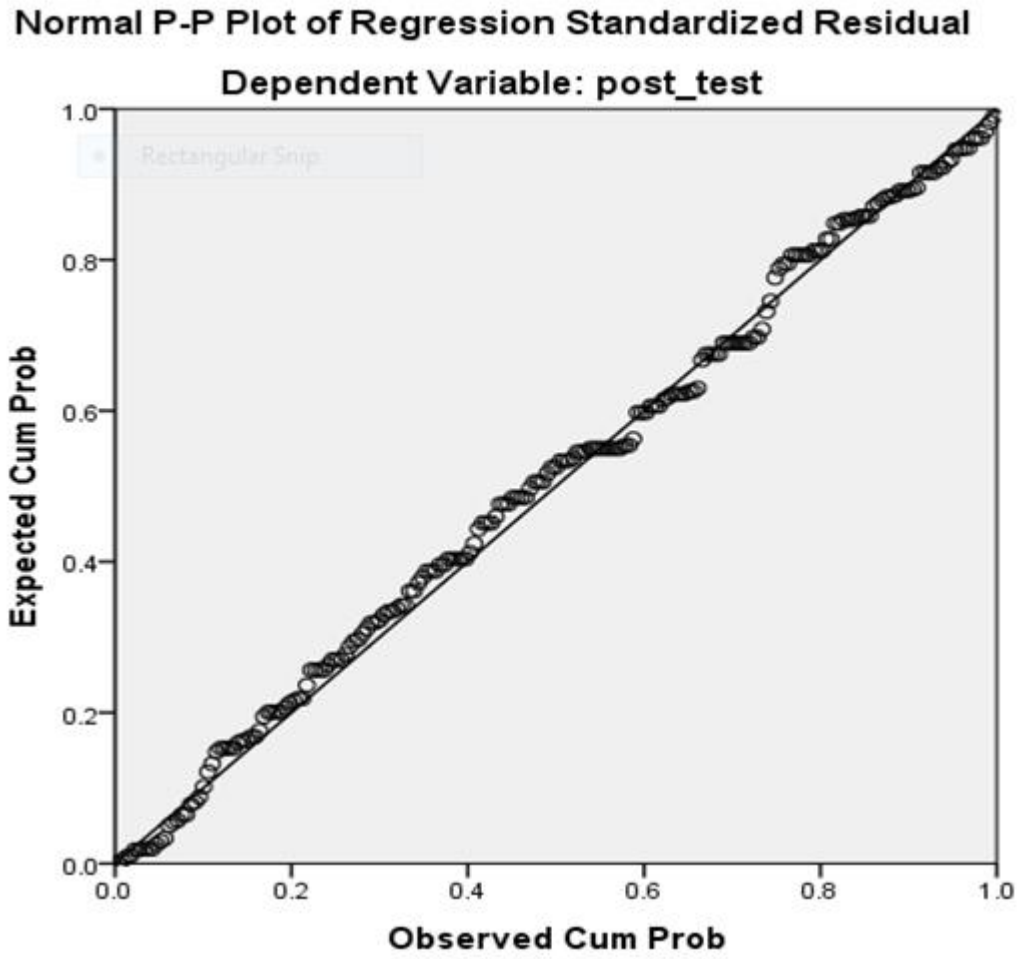


Figure 5.10: Normality P-P Plot of Regression Standardised Residual

The normal probability plot (Chambers, Cleveland, Kleiner, & Tukey, 1983) is a graphical technique for assessing whether or not a data set is approximately normally distributed. In the Normality Probability plot given in Figure 5.10, it is evident that the points form an approximate straight line from bottom left to right. This suggests there are no outliers and other assumptions like normality and linearity are not violated. This shows that the data set is approximately normally distributed.

Figure 5.11 below gives a scatterplot of the standardised residual analysis.

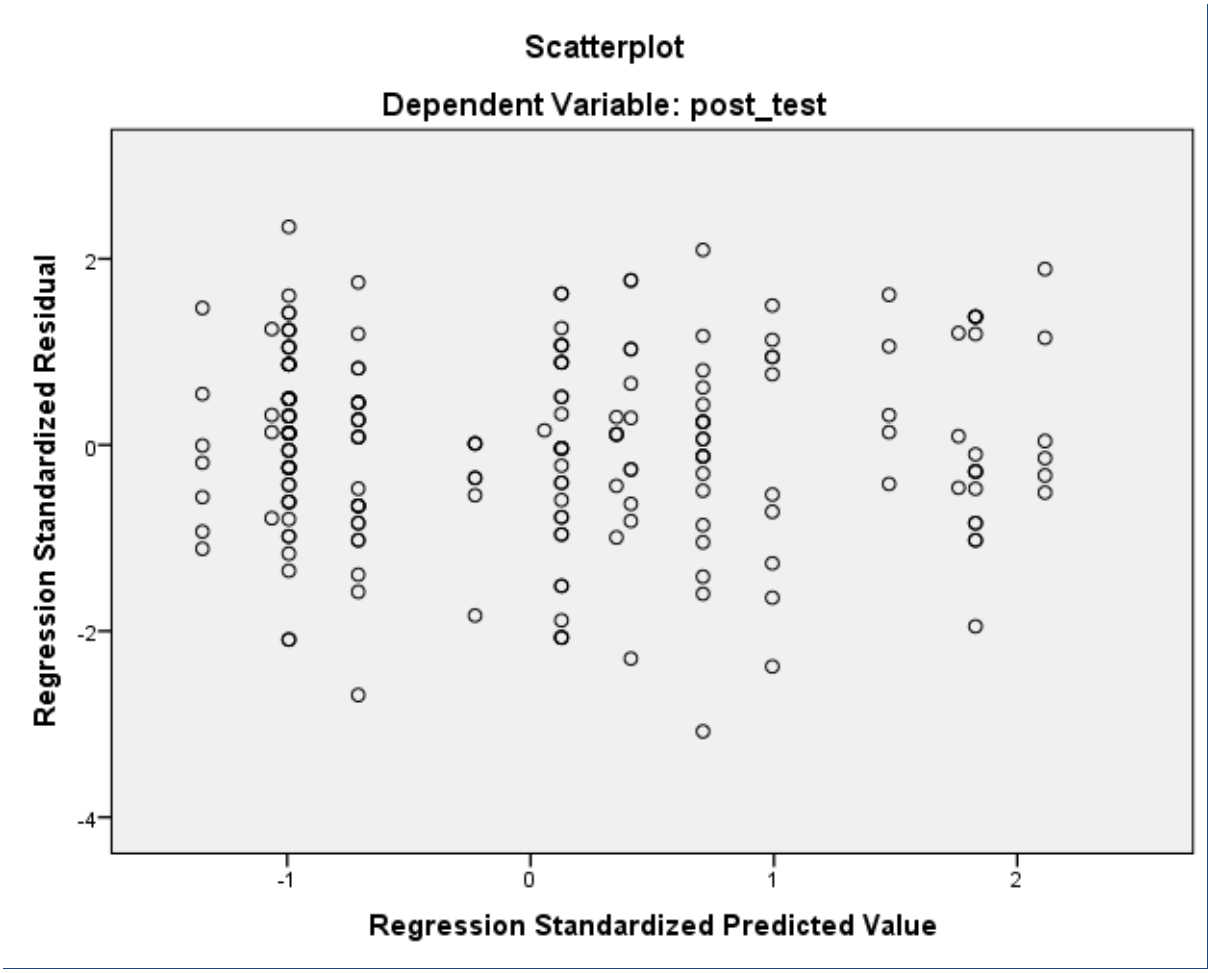


Figure 5.11: Scatterplot of the standardised residual analysis

In the scatterplot of the standardised residuals (see Figure 5.11), the residuals are roughly rectangularly distributed, with most scores concentrated in the centre (along the 0 point of reference). There is no clear or systematic pattern to the residuals (e.g. curvilinear or higher on one side than the other) that indicates that the data meet the assumptions of the errors being normally distributed and the variances of the residuals being constant (Freund et al., 2006; Leech et al., 2005). Freund et al. (2006) further state that, if the scatterplot of residuals against predicted value shows no pattern, it indicates the normality of residuals and a homogeneous error of variance across the predicted values. Figure 5.11 shows that there are no deviations from a centralised rectangle suggesting that there is no violation of the assumptions. The presence of outliers can also be detected from the scatterplot. Tabachnick and Fidell (2001) define outliers as cases that have a standardised residual (as displayed in Figure 5. 11) of more than 3.3 or less than -3.3. From Figure 5.11, it is evident that there are no outliers and this suggests that there is no violation of the assumptions. Figure 5.12 below

gives a histogram of the standardised residual analysis.

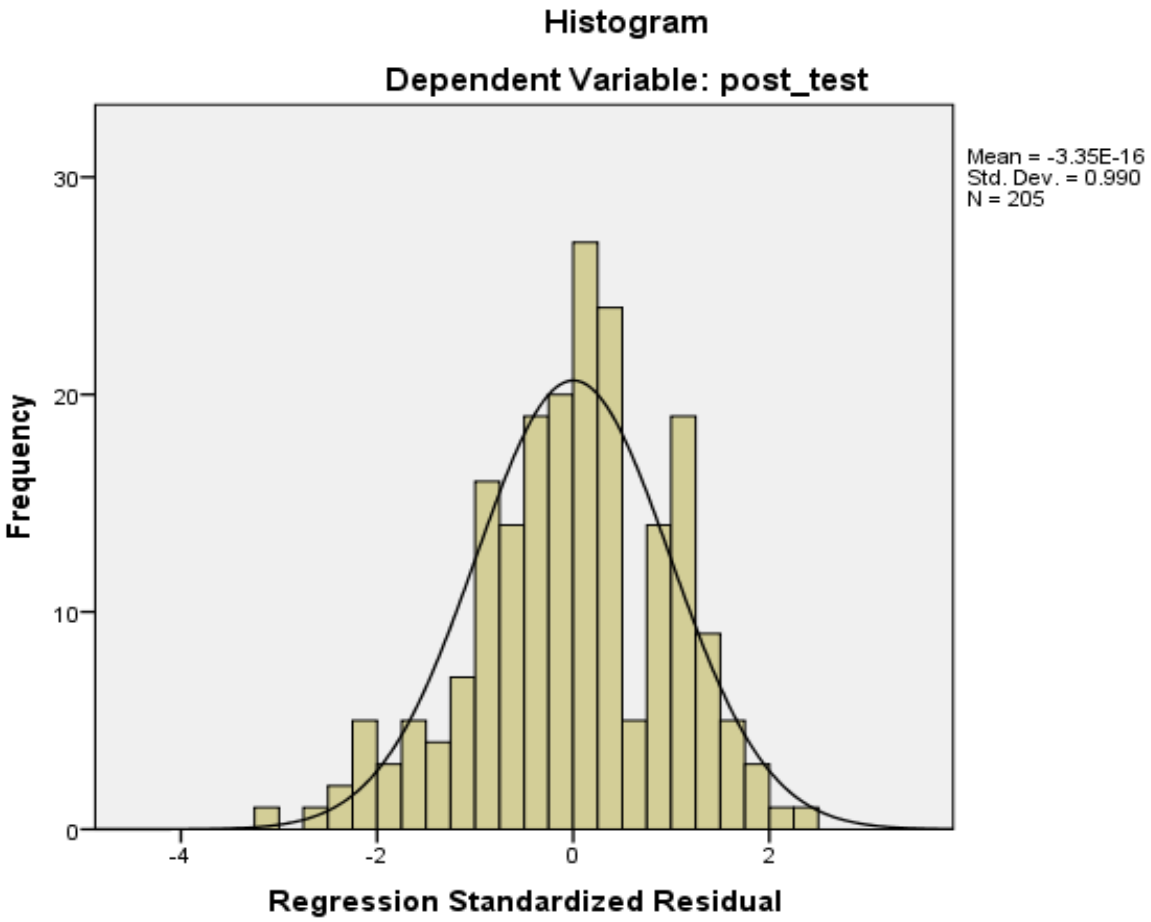


Figure 5.12: A Frequency histogram of the standardised residual analysis

Presented graphically, the shape of the curve and the width of the base would clearly show the difference in terms of the distribution of the achievement scores. As presented in Figure 5.12 above, the achievement scores for the grade 11 learners in electricity and magnetism are mainly centrally concentrated normally, indicating a greatly distributed set of scores shown by the SD of 0.990. Hence, the major assumptions of multiple regressions were satisfied and that supported the researcher's decision to conduct a standard regression analysis on the data.

5.3.3.3 Regression model fit test for grade 11 learners' academic achievement

Once the assumptions of multiple regression were checked and found to be satisfied, the regression model fit test was conducted on physical science learners' academic achievement scores to determine whether the best linear combination of sensing/intuitive, visual/verbal,

active/reflective and sequential/global can predict learners' academic achievement. The output of regression analysis is presented in Tables 5.28 and 5.29.

Table 5.28: Model summary

Model	R	R Square	Adjusted R square	Std. error of the estimate
1	0.146	0.021	0.002	10.826

*a. Predictors: (Constant), active/reflective, sensing/intuitive, visual/verbal, sequential/global.

* b. Dependent Variable: academic achievement.

Table 5.28 illustrates the Regression Model Summary of grade 11 science learners' academic achievement scores. Looking at the Model Summary box (Table 5.28), the given value R is 0.146 and R square value is 0.021. This indicates how much of the variance in the dependent variable (academic achievement) is explained by the model (including the four independent variables). If expressed as a percentage, the model explains 2.1% of the variance in academic achievement in electricity and magnetism. This is a low value when compared to some of the results that are reported in the literature. This implies that the model was fairly poor to predict science learners' academic achievement in electricity and magnetism. Thus, the regression test suggests that the total explanatory power of learning styles in explaining academic achievement in electricity and magnetism was small. This implies that there were other important instructional variables, other than learning styles, which could explain academic achievement.

The ANOVA part of the regression analysis (see Table 5.28) revealed whether predicting 2.1% variation in academic achievement in electricity and magnetism from Felder-Silverman learning style dimensions was statistically significant or not.

Table 5.29: The ANOVA table for significance test of the R^2 of the regression model

Model		Sum of Squares	Df.	Mean Squares	F	Sig.
1	Regression	508.735	4	127.184	1.085	0.365
	Residual	23438.660	200	117.193		
	Total	23947.395	204			

*a. Predictors (constant): active/reflective, sensing/intuitive, visual/verbal, sequential/global.
*b. Dependent variable: academic achievement

As can be seen from the ANOVA (Table 5.29), the model of sensing/intuitive, visual/verbal, active/reflective and sequential/global failed to significantly predict academic achievement on the PSAT, F (4, 200) =1.085, p = 0.365. In addition, the coefficients in Table 5.29 show that none of the predictors have a statistically significant contribution to the regression equation. This means that the outputs of the regression test showed that the prediction of grade 11 science learners' (F (4, 200) = 1.085, p = 0.365) academic achievement in electricity and magnetism from the linear combination of learning styles was not statistically significant. Therefore, the regression model has failed to demonstrate a statistically significant prediction of variations in academic achievement from the different learning style preferences.

Beta values under Standardised Coefficients (Table 5.27) determine which of the variables included in the analysis contributed to the prediction of the dependent variable. Standardised means that values for each of the different variables were converted to the same scale for comparison. However, the beta values were slightly lower indicating that they make a lesser contribution and that being a visual or verbal, sensing or intuitive, active or reflective, sequential or global learner did not contribute to predicted measures of academic achievement in electricity and magnetism.

In general, the correlational statistics and regression analysis show that there was no statistically significant relationship between academic achievement of learners and learning style preferences among high school learners. Table 5.30 summarises the Regression model fit test.

Table 5.30: Model Summary: The regression model fit test combined effect of learning style categories on academic achievement

R: 0.146 **R^2**: 0.021 **Adjusted R square**: 0.002 **Std. error of the estimate**: 10.826					
ANOVA					
Model	**Sum of Squares**	**Df**	**Mean square**	**F**	**Sig.**
Regression	508.735	4	127.184	1.085	0.365
Residual	23438.660	200	117.193		
Total	23947.395	204			

Table 5.30 illustrates the combined effect and contribution of the learning styles on academic achievement. The combination of the four learning style categories accounted for 2.1% of the variances (R^2: 0.021; *p*: 0.365). Table 5.30 therefore suggests that, statistically, the four learning style categories combined do not contribute significantly to the academic achievement of the grade 11 learners in electricity and magnetism at the four high schools in Mthatha.

5.4 Comparing learners' academic achievement in electricity and magnetism with learners' learning style preferences

This section compares the academic achievement of learners with different learning style preferences to reveal whether a particular learning style preference enhances learners' academic achievement in electricity and magnetism. An independent sample t-test was used to empirically compare the physical science learners' academic achievement against their learning style preferences.

5.4.1 Comparison of active and reflective learners' academic achievement scores in electricity and magnetism

The section compares the learning style preferences of active and reflective learners and their academic achievement in electricity and magnetism to see if any particular learning style category is successful in improving learners' academic achievement in physical sciences. Firstly, the average class mark for active and reflective learning style category was compared against their learning style preferences. Observations that were made are summarised in

Figure 5.13 below.

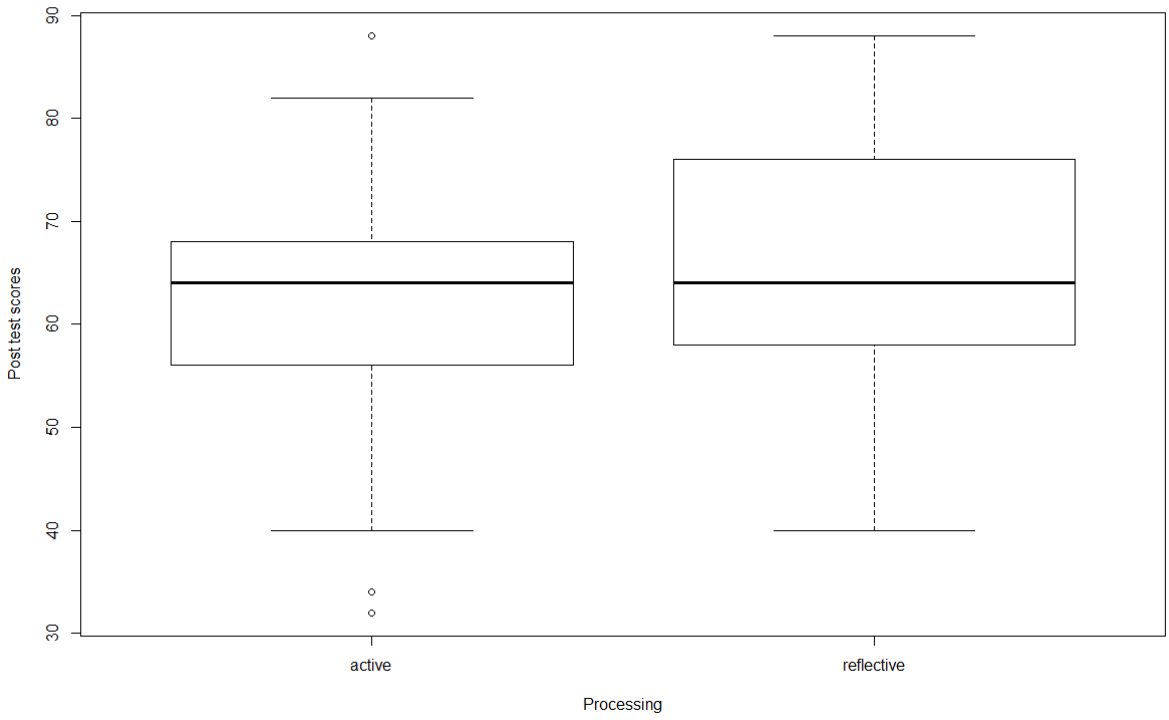


Figure 5.13: Comparison of average scores for active and reflective learners

An independent sample t-test was computed to observe if there was a statistically significant difference in active and reflective learners' academic achievement in electricity and magnetism. In addition to the t-test comparison of means of active/reflective learners' academic achievement among grade 11 physical science learners, the indices of collinearity statistics presented earlier in section 5.6.3 were studied. It was also clear from Table 5.27 that the β coefficient (β=0.079, p-value=0.262) values for the active/reflective learning style dimension was small and the p-value was above 0.05. This minimum β and significant p-value tells us that the contribution or probability of predicting academic achievement in electricity and magnetism from active/reflective learning style category was not statistically significant. Though the contributions of active/reflective learning style dimension to the regression model was not statistically significant, an independent sample t-test was used to check if being active or reflective learners resulted in statistically significant differences in academic achievement in electricity and magnetism.

Table 5.22 also illustrates that the means of measures of academic achievement in electricity

and magnetism was 63.5 for active learners and 65.4 for reflective learners. The difference between the means for academic achievement of active and reflective learners was 1.9. The question is whether this difference was statistically significant or was due to chance. An independent sample t-test was therefore done to answer this question. The numerical results are displayed in t-test summary table (Table 5.31). The table lists assumptions of variances, difference between means, t-value and the p-value.

Table 5.31: Comparing active and reflective learners' academic achievement scores in electricity and magnetism (post-test values)

		Levene's test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	Df	Sig. (2-tailed)	Mean difference	Std. Error difference
Achievement	Equal variances assumed	1.846	0.176	-1.250	203	0.213	-1.946	1.556
	Equal variance not assumed			-1.213	147.472	0.227	-1.946	1.604

According to Table 5.31 above, the variance was not statistically significantly different because the p-value of the Levene's test was 0.176, which was greater than 0.05 levels. Therefore, the assumption of homogeneity of variance was satisfied to conduct an independent sample t-test to compare the difference between the means of measures of academic achievement of active and reflective learners.

From Table 5.31, the output of an independent sample t-test based on the assumptions of equal variance at α=0.05, was t (203) = 0.1.250, p-value=0.213. This was not statistically significant. In other words, it can be concluded that there was not a statistically significant different academic achievement between active and reflective learners in electricity and magnetism among high school learners. The researcher therefore concludes that being an active or reflective learner does not make the learner learn better than the other learning style preferences. This negative mean difference between the academic achievement of active and reflective learners in the study was due to chance; whether learners were active or reflective, their academic achievement in electricity and magnetism was not statistically significant.

5.4.2 Comparisons of sensing and intuitive learners' academic achievement in electricity and magnetism

This section compares the learning style preferences of sensing and intuitive learners and their academic achievement in electricity and magnetism to see if any particular learning style category is successful in improving learners' academic achievement in physical sciences. Firstly, the average class mark for the sensing and intuitive learning style category was compared against their learning style preferences. Observations were made and these are summarised in the Figure 5.14 below.

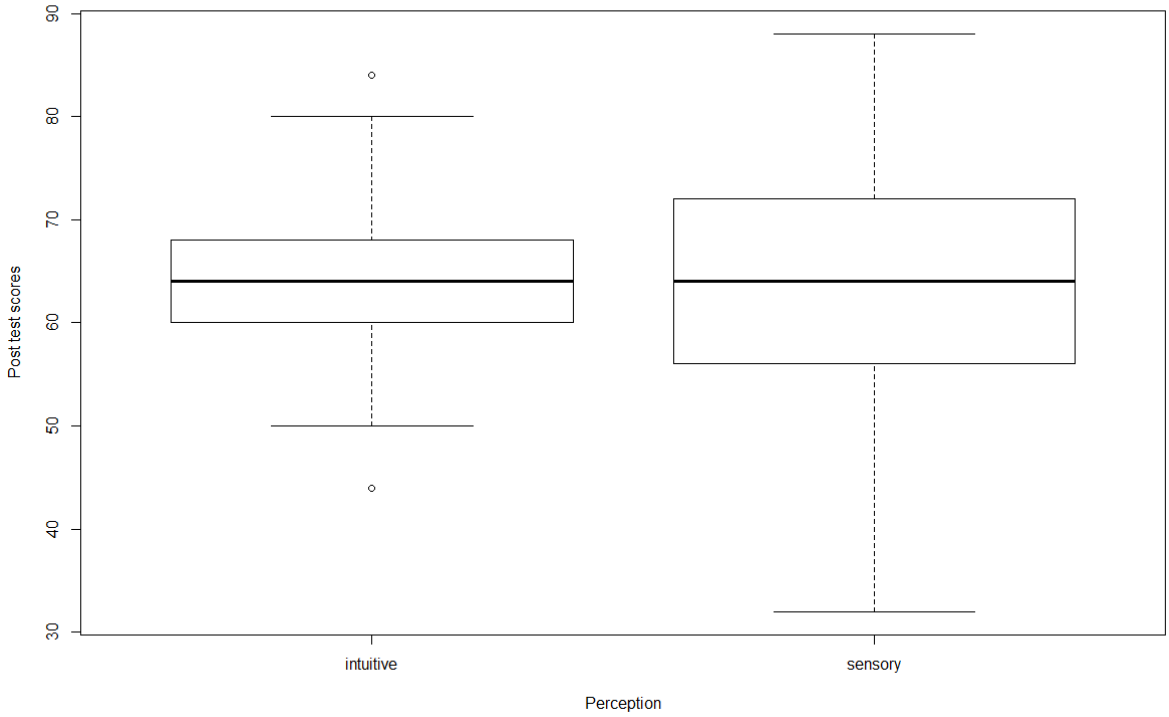


Figure 5.14: Comparison of average scores for sensing and intuitive learners

The achievement of sensing and intuitive learners in electricity and magnetism was further compared using an independent sample t-test. This comparison was necessary to know which learning style category best enhances learners' academic achievement in electricity and magnetism. The β coefficients observed in Table 5.27 for grade 11 learners (β=-0.019, p-value=0.787) show that the sensing/intuitive learning style contribution to grade 11 learners' academic performance in electricity and magnetism was very small. The p-value also shows that the sensing/intuitive learning style was not a statistically significant contributor to grade

11 learners' academic achievement in electricity and magnetism. Therefore, the smallest β and p-value were well above α=0.05, a significant level which suggests that the contribution and probability of predicting academic achievement in electricity and magnetism from sensing/intuitive learning style dimension was not statistically significant. Even though the contributions of the sensing/intuitive learning styles dimension to the regression model was not statistically significant, an independent sample t-test was used to check whether being a sensing or intuitive learner accompanies statistically significant differences in grade 11 learners' academic achievement in electricity and magnetism.

Table 5.22 also presents the means of scores in grade 11 learners' academic achievement in electricity and magnetism for the sensing (64.2) learners and intuitive (64.2) learners. There is no difference between the mean of sensing and intuitive learners. Therefore, the assumption of homogeneity of variances was checked using the Levene's statistic before using the independent sample t-test (see the Table 5.32 below)

Table 5.32: Comparing sensing and intuitive learners' academic achievement scores in electricity and magnetism (post-test values)

		Levene's test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	Df	Sig. (2-tailed)	Mean difference	Std. Error difference
Achievement	Equal variances assumed	3.201	0.075	0.013	203	0.989	0.027	2.064
	Equal variance not assumed			0.016	54.584	0.987	0.027	1.741

The Levene's statistics from Table 5.32 showed that the variances were not statistically significant, because the p-value was 0.075 which was greater than 0.05. Therefore, the assumption of homogeneity of variance was fulfilled for further statistical significance testing of the difference between the means of measures of academic achievement of sensing and intuitive learners via an independent sample t-test. The independent sample t-test numerical results are displayed in t-test summary table (Table 5.32). It lists the assumptions of variances, difference between means, t-value, and the p-value.

From Table 5.32, the output of an independent sample t-test, based on the assumptions of

equal variance at α=0.05, was t (203) =.0.013, p-value=0.989. This was not statistically significant. In other words, it can be concluded that there was no statistically significant difference in grade 11 learners' academic achievement in electricity and magnetism between sensing and intuitive learners. The researcher's conclusion is that being a sensing or intuitive learner does not make any difference in the learners' post-test scores in electricity and magnetism. This is because, whether the learners were sensing or intuitive, their academic achievement in electricity and magnetism was not statistically significant.

5.4.3 Comparisons of visual and verbal learners' academic performance scores in electricity and magnetism

This section compares the learning style preferences of visual and verbal learners and their academic achievement in electricity and magnetism to see if any particular learning style category is successful in improving learners' academic achievement in physical sciences. Firstly, the average class mark for visual and verbal learning style category was compared against their learning style preferences. Observations were made and these are summarised in Figure 5.15 below.

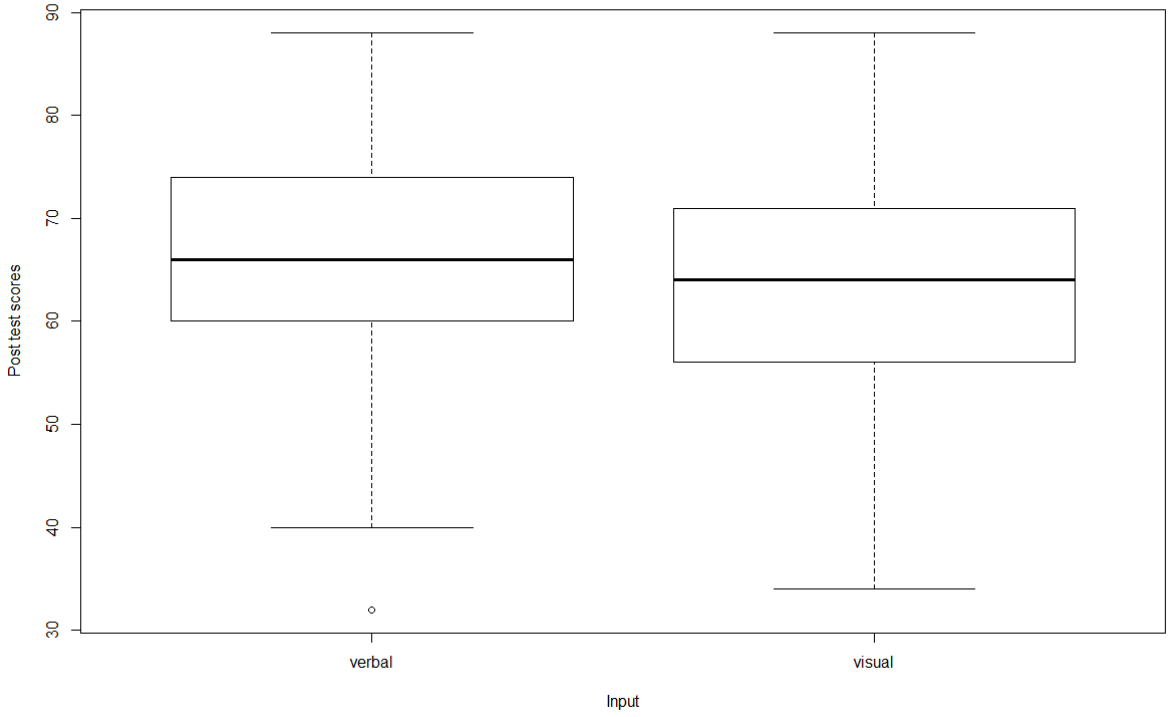


Figure 5.15: Comparison of average scores for visual and verbal learners

The comparison between visual learners' and verbal learners' academic achievement in grade 11 learners' academic achievement in electricity and magnetism was computed. The β coefficients in Table 5.27 for grade 11 learners (β=0.116, p-value=0.103) show that the contribution of a visual/verbal learning style to grade 11 learners' academic achievement in electricity and magnetism was small. This small contribution of visual/verbal learning to grade 11 learners' academic achievement in electricity and magnetism was not statistically significant. Thus, the β and p-value suggest that the contribution and probability of predicting grade 11 learners' academic achievement in electricity and magnetism from a visual/verbal learning style dimension was not statistically significant. Although contributions of visual/verbal learning styles' dimension to the regression model was not statistically significant, an independent sample t-test was used to check whether being a visual or verbal learner accounts for significant differences in grade 11 learners' academic achievement in electricity and magnetism.

Table 5.22 also shows that the mean for grade 11 learners' academic achievement in electricity and magnetism was 63.3 for visual learners, and 66.1 for verbal learners. This shows that the differences between the means of the two groups (i.e. between the mean of visual and verbal learners) was 2.8. The question is whether this difference was statistically significant or was due to chance. An independent sample t-test was therefore done to answer this question. The assumption of homogeneity of variances was tested on the data using the Levene's test for statistics (Leech et al., 2005) before applying the result of an independent sample t-test. The numerical results of the independent sample t-test are displayed in t-test summary table (Table 5.33). The table lists the assumptions of variances, difference between means, t-value and the p-value.

Table 5.33: Comparing visual and verbal learners' academic achievement scores in electricity and magnetism (post-test values)

		Levene's test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	Df	Sig. (2-tailed)	Mean difference	Std. Error difference
Achievement	Equal variances assumed	0.178	0.673	-1.736	203	0.084	-2.809	1.618
	Equal variance not assumed			-1.682	115.670	0.095	-2.809	1.670

In Table 5.33, the Levene's statistics show that the variances were not statistically significantly different, because the p-value of 0.673 was greater than 0.05. Therefore, the assumption of homogeneity of variance was satisfied for further testing on the difference between the means of measures of academic performance of visual and verbal learners.

It is evident from Table 5.33 that an independent sample t-test based on the assumptions of equal variance at $\alpha=0.05$ was $t(203) = 1.736$, p-value=0.084. This was not statistically significant. In other words, it can be concluded that there was no statistically significant difference in grade 11 learners' academic achievement in electricity and magnetism between grade 11 visual and verbal learners in Mthatha schools. The researcher's conclusion here is that, being a visual or a verbal learner does not make any difference to grade 11 learners' academic achievement in electricity and magnetism. Therefore, the difference observed between the mean of grade 11 visual and verbal science learners' academic achievement (i.e. 2.8) in this study could be due to chance. The independent sample t-test showed that whether the learners were being visual or verbal, their academic achievement in electricity and magnetism was not statistically significant.

5.4.4 Comparisons of sequential and global learners' academic achievement in electricity and magnetism

This section compares the learning style preferences of sequential and global learners and their academic achievement in electricity and magnetism to see if any particular learning style category is successful in improving learners' academic achievement in physical sciences. Firstly, the average class mark for the sequential and global learning style category was compared against their learning style preferences. Observations were made and these are summarised in Figure 5.16 below.

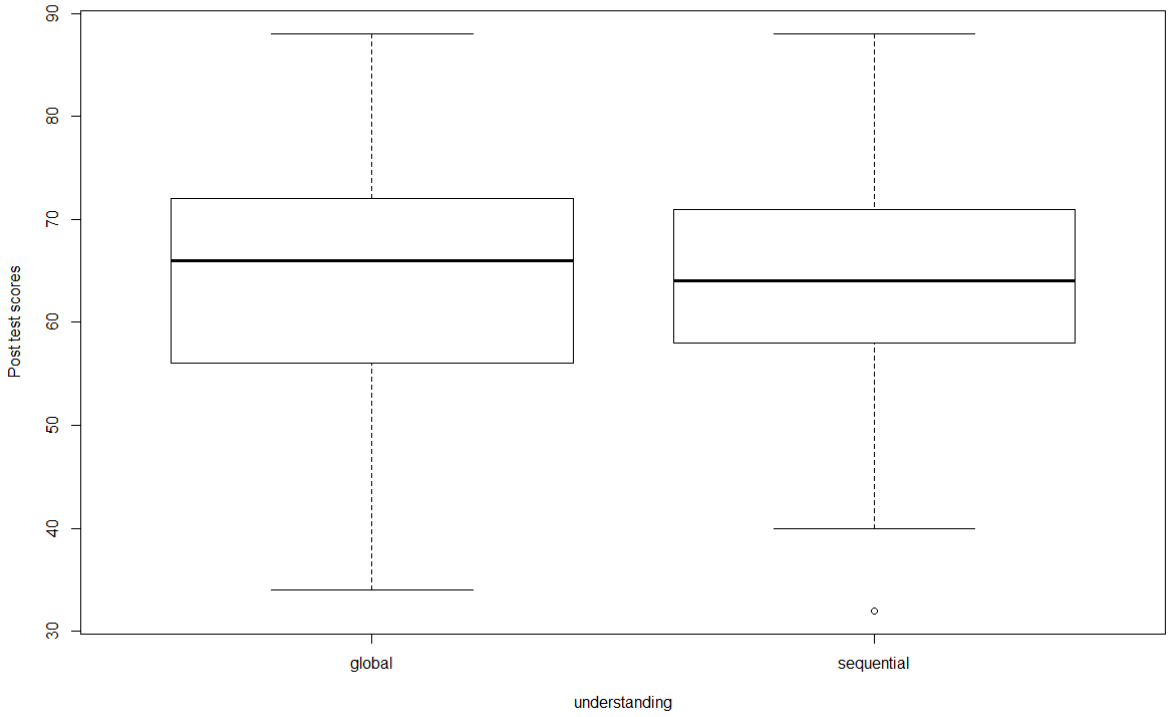


Figure 5.16: Comparison of average scores for sequential and global learners

An independent sample t-test was computed to observe the difference between sequential and global learners' academic achievement in electricity and magnetism.

Besides the t-test, indices of the collinearity statistics presented in Table 5.27 were studied. The β coefficient for sequential/global learning style in Table 5.27 for grade 11 learners (β=0.019, p-value=0.786) was small and the p-value was above 0.05. This shows that the sequential/global learning style preference was not a statistically significant contributor to grade 11 learners' academic achievement in electricity and magnetism. Thus, β and p-value for the predictor variable sequential/global learning style dimension suggests that the contribution and probability of predicting grade 11 learners' academic achievement in electricity and magnetism in relation to the sequential/global learning style dimension was not statistically significant. Although the contributions of the sequential/global learning styles dimension to the regression model was not statistically significant, an independent sample t-test was used to further check whether being a sequential or global learner was a source of difference in academic achievement in electricity and magnetism.

Table 5.22 shows that the mean of academic achievement in electricity and magnetism was

64.1 for sequential learners and 64.5 for global learners. The difference between the means of sequential and global learners' academic achievement was 0.4. The question here is whether this difference was statistically significant or resulted from chance. An independent sample t-test was therefore done to answer this question. The numeric results of the t-test are displayed in t-test summary table (Table 5.34).

Table 5.34: Comparing sequential and global learners' academic achievement scores in electricity and magnetism (post-test values)

		Levene's test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	Df	Sig. (2-tailed)	Mean difference	Std. Error difference
Achievement	Equal variances assumed	1.109	0.294	-0.218	203	0.828	-0.362	1.659
	Equal variance not assumed			-0.210	103.778	0.834	-0.362	1.726

Table 5.34 shows that the p-value of the Levene's test was 0.294 which was greater than 0.05. This implies that the variances were not statistically significantly different. Therefore, the assumption of homogeneity of variance was satisfied for statistically significance test on the difference between the means of sequential and global learners' academic achievement.

Table 5.34 shows that the output of an independent sample t-test based on the assumptions of equal variance at $\alpha=0.05$ was $t(203)=-0.218$, p-value=0.828. This was not statistically significant. In other words, it can be concluded that there was no statistically significant difference between the means of sequential and global learners' academic achievement in electricity and magnetism.

The researcher's conclusion is that being a sequential or global learner did not make any difference to academic test scores in electricity and magnetism among grade 11 learners. Therefore, the achievement mean difference in the study was due to chance.

5.5 Chapter summary

The chapter presents and discusses the results of the quantitative phase of this study. The results gave answers to what the learning style preferences of learners were, thus answering

research question 1. It was found that there were more active learners compared to reflective learners, more sensing learners compared to intuitive learners, more visual learners compared to verbal learners and more sequential learners compared to global learners. From the analysis of the FSILSQ, it was found that a majority of the females have preferences for the active, sensory, visual and sequential learning style dimensions, compared to males. However, from a general perspective, it can be inferred that, regardless of the gender differences, a majority of the physical sciences learners prefer to perceive information in both forms of active, sensing, visual and sequential learning style categories.

To answer research question 4, which investigated the impact of learning style-based instructions on learners' academic achievement in electricity and magnetism, data from PSAT were analysed and presented. It was found that the mean scores in the pre-test and post-test for the total sample were significantly different. This reveals that there exists significant difference in the mean post-test scores on achievement in electricity and magnetism of the experimental and control groups for the total sample. The experimental group scores were significantly higher than the control group scores.

In order to establish the relationship and observe the degree of association between learning style preferences and academic achievement among the respondents in the experimental group, the Pearson Moment Correlation Coefficient and significance tests were computed. It was found that the relationships among the learning style dimensions were not greater than 0.2. This shows that low relationships were observed among the learning style dimensions in the correlations tables. Based on the result, there was no statistical significant correlation between the academic achievement and the learning style preferences of the learners.

A one-way analysis of variance (ANOVA) was conducted to investigate the existence of possible differences among learning style categories and academic achievements, as well as by gender. To determine whether any of the differences between the means are statistically significant, a comparison between the p-value and the significance level was done to assess the null hypotheses (H_o). Results showed that there was no significant effect of academic achievement on learning style preferences at $p<0.05$ level for the following conditions $F (1, 203)=1.563$, $p=0.213$ for active/reflective; $F (1, 203)=0.000$, $p=0.989$ for sensory/intuitive; $F (1, 203)=3.013$, $p=0.084$ for visual/verbal; $F (1, 203)=1.539$, $p=0.216$ for sequential/global learning styles.

Data of the study were further subjected to the regression model fit test and the indices of the coefficient of determination (R square) and ANOVA tests for R^2 of the regression model were used to empirically answer the third research question. The regression test suggests that the total explanatory power of learning styles in explaining academic achievement in electricity and magnetism was small. This implies that there were other important instructional variables, other than learning styles, which could explain academic achievement. In addition, the ANOVA model of sensing/intuitive, visual/verbal, active/reflective and sequential/global failed to significantly predict academic achievement on the PSAT, F (4, 200)=1.085, p=0.365. The outputs of the regression test showed that the prediction of grade 11 science learners' (F (4, 200)=1.085, p=0.365) academic achievement in electricity and magnetism from the linear combination of learning styles was not statistically significant. Therefore, the regression model failed to demonstrate a statistically significant prediction of variations in academic achievement from the different learning style preferences. Thus, statistically, the four learning style categories combined do not contribute significantly to the academic achievement of the grade 11 learners in electricity and magnetism at the four high schools in Mthatha.

In concluding the quantitative phase of the study, the researcher posits that implementing learning style-based instructional strategies impact significantly on learner academic achievement in electricity and magnetism, although there was not a particular learning style preference that helps learners to be successful in learning the concept electricity and magnetism considered under the investigation.

In the next chapter, the impact of culture on learners' learning style preferences is explored in greater detail by examining the results from the interviews conducted with a number of learners and relating them to the literature.

CHAPTER SIX
TEACHERS' AND LEARNERS' PERCEPTIONS OF THE ROLE OF CULTURE ON LEARNERS' LEARNING STYLE PREFERENCES

6.0 Introduction

Chapter Three detailed the research methodology followed in the study to answer the research questions posed in Chapter One. This chapter is the second which engages with the research findings. The chapter analyses the data collected based on methods discussed in the previous chapter. The chapter begins with the presentation of results from the interview data pertaining to the second research question: "How can knowledge of the cultural attributes of learning be used to determine the most likely learning styles favoured by learners?" The emphasis was on determining the extent to which learners' cultural backgrounds translate into learners' learning styles differences in the science classroom. Therefore, the results were discussed in the light of findings from related literature. As previously explained in Chapter Two, the Hofstede (2001) model was used to describe the cultural attributes of learners and this was related to Felder-Silverman's learning styles. The choice of this model by Hofstede (2001) was established on the fact that it expounds the cultural characteristics of learners thus simplifying the characteristics which could be easily related to the ways learners prefer to learn in a particular culture. This is crucial as it points to the explicitness of the cultural characteristics and their relation to learning style preferences.

6.1 Results from learner interviews

In this section, the results of the participants' interviews are presented. In presenting the results, learners' responses from the interviews are presented first, followed by teacher's responses and the two results are discussed in the section that follows. The themes are enumerated and a sub-theme follows with a table that details ontological aspects of the sub-theme, a quote to support the sub-theme and interpretation is presented last.

6.1.1 Profile of participants

Details of the learners who were interviewed are presented in Table 6.1.

Table 6.1: Learning style profiles of participants who were interviewed

Learner Code	Grade	Gender	Learners Learning style profile			
			Active/Reflective	Sensory/Intuitive	Visual/Verbal	Sequential/Global
MLLA	11	Male	Active	Sensory	Visual	Global
FLLB	11	Female	Active	Sensory	Verbal	Sequential
MLLC	11	Male	Reflective	Intuitive	Visual	Sequential
FLLD	11	Female	Active	Sensory	Verbal	Global
MLLE	11	Male	Active	Sensory	Verbal	Global
FLLF	11	Female	Reflective	Intuitive	Visual	Sequential
MLLG	11	Male	Reflective	Intuitive	Verbal	Sequential
FLLH	11	Female	Reflective	Intuitive	Visual	Global
MLLI	11	Male	Active	Sensory	Verbal	Sequential
FLLJ	11	Female	Reflective	Sensory	Visual	Global
MLLK	11	Male	Active	Sensory	Visual	Global
FLLL	11	Female	Active	Intuitive	Verbal	Sequential
MLLM	11	Male	Reflective	Intuitive	Verbal	Global
FLLN	11	Female	Active	Sensory	Verbal	Sequential
MLLO	11	Male	Reflective	Intuitive	Visual	Sequential
FLLP	11	Female	Reflective	Intuitive	Visual	Global

Table 6.1 shows that there was a gender balance in the sampling of participants for the interviews. There were eight females (n=8) and eight males (n=8). Each of these participants has varying learning style profiles. The results are analysed theme by theme and according to the way they appear on the interview schedule. The results from each of the questions asked in the individual interviews are discussed in the section that follows. Full details of the responses are given in Appendix K.

Influence of learners' home backgrounds on their learning style preferences

This theme is about whether the home background characteristics influence learners' learning style preferences. These include interview questions, such as how learners learn at home, how learners were raised at home and how this influences their learning style preferences. The responses that indicate how learners learn in their home cultural backgrounds are presented as sub-themes.

How learners learn at home

All of the ten interviewees responded to this question. There were five girls and five boys who were interviewed, as discussed in Chapter Four of the study. When the learners were

probed on how they learned at home, their responses indicated that they relied heavily on verbal information received from adults in authority, without questioning it, basically in the form of directives. Most of the interviewed learners highlighted respect for authority. Some of the typical responses are given below:

> *FLLD: I learn the most at home by listening and following orders from an older person than me.*
>
> *FLLB: I learn from my parents or an adult in authority mostly through verbal information when they talk to me or confront me to do the right thing.*
>
> *MLLC: I learn through what they say and act in situations. In other words, I learn to do things as my parents told me to do.*
>
> *MLLA: I learn from them sitting me down and talking to me in a gentle way and through their actions.*

References were also made by the learners on learning from visual information, mostly through observation. This illustrates visual learning style. For instance, a learner narrated that, when an elderly person wants to demonstrate how a particular food is prepared, the child is asked to look at how it is done after which the child is made to try it out on another day until she becomes proficient in preparing that particular meal. Two learners stated:

> *MLLG: I learn from the way they act and do things, which is very positive and beneficial to me.*
>
> *MLLE: I learn things when I see them doing it as well. My parents show me how certain things are done.*

It is apparent that learners mostly learn at home through visual and verbal learning styles. Many of the attributes of these types of learning styles were alluded to in the interviews. This means that emphasis was placed on visual strategies and conceptual illustrations for information processing in a learning situation. It is apparent therefore that a person's learning style is the means he/she uses strategies to organise information in any learning environment.

How learners were raised at home

Learners' responses indicated similar cultural values that have not been contaminated by

social media and colonisation. A common trend identified from the learners' responses was that adult, elders, leaders and seniors in the society should not be interrogated, and that elders should be accorded with respect. The learners narrated:

> *FLLP: I have only known my grandmother whom I live with since I was five years old. My grandmother tells me always to respect older people and people in authority. She taught me always to listen and not to argue about anything.*

> *MLLM: I was brought up by my grandmother. I was taught to respect my elder s. I was raised with good morals and have been encouraged to always do the right thing.*

Showing appreciation and being grateful was one of the moral values that are handed down over generations, which shows that many townships folks have upheld their cultural tenets and continue to hand down these tenets over generations. One learner specifically stated:

> *MLLK: My parent taught me how to be patient, respectful and humble. I was taught to respect the elderly and when receiving items from other people, always be grateful.*

References were also made to masculine and feminine cultural attributes as a way of learning at home. Masculinity and femininity is associated with the division of societal roles between males and females. It manifests itself as hostile versus more "submissive" conduct (Manikutty et al., 2007). One learner commented:

> *FLLH: I was raised by my parents. I was taught that the man leads or heads the family and works harder than any member in the family, and should be respected.*

These responses are testimonies that most people have upheld their traditional tenets and continue to hand down these tenets to their younger generations. These cultural beliefs and values are finely deep-rooted through teachings and experiences within families' structures and societal systems. Nevertheless, if the schooling system is customarily insensitive to these beliefs and practices, the educational influence may be devastating. Holtbrügge and Mohr (2009) contend that "some cultural values can affect learning style preferences of learners, while other features do not seem to have an impact" (p. 24). Holtbrügge and Mohr (2009) further suggest that teachers ascertain the cultural tenets that influence on learners' learning styles in order to move closer to "the desirability of the convergence of educational systems" because educational systems draw predominantly from cultural values and address national goals and aspirations (p. 24).

Influence of the way learners were raised on how they relate to their science teacher in the classroom

The learners were asked to describe how the way they were raised at their homes influenced the way they related to their science teachers in the science classroom. They emphasised the need to respect the teacher as the one in authority and not to question his/her power. This is evidence of power-distance cultural attribute. Power-distance is the degree to which the society consents and expects an uneven dissemination of authority. In the school context, it means the interrelationship between the teacher and learners. Hofstede (1986) argues that power-distance plays a significant role in determining learner/teacher relationships. The teacher is ranked higher because of the information and power entrusted in him/her. Therefore, the teacher's knowledge and instructions are taken as reliable and are not probed (Hofstede, 1986; 2002). Thus, class discussions tend to be clarifications rather than actual debates on what the teacher has taught. Learners look up to their teachers and this is a characteristic of visual/verbal learning style (or input) of the FSLS model. Two learners narrated:

> *FLLL: Sometimes, I choose to keep quiet if my view point is not considered by the teacher to be valid. This is because; I was raised at home not to engage in any form of argument with teachers or elderly people.*

> *MLLI: Sometimes, I take things the way they were without questioning anyone, because I respect my teacher and I do not want to upset him if I have to question his authority, although I may not agree with his view point all the time.*

Findings from the learners' responses on this theme show that educational policies should infuse some aspects of culture into the school context. It is essential for teachers, to be cognisant of the learning characteristics of the learners they teach in order to improve their achievements. The researcher believes that, if teachers embrace their learners' cultural characteristics in the teaching-learning processes and become flexible in terms of modifying teaching strategies in their science classrooms, this could improve learner performance in the subject. As indicated by Ingalls, Hammond, Dupoux and Baeza (2006), educational goals could be enriched and could also relieve uncertainties that relate to loss of group distinctiveness, hostility and nervousness during the lesson.

The foundation of a healthy relationship is built as teachers take the opportunity to interact

and learn from their learners. The way learners may react to adults in authority in their culture may be incongruent with what is expected at school. For example, keeping eye contact might seem inappropriate or impolite in the learners' home culture whereas, in school, it is acceptable for a learner to keep eye contact with the teacher. Three learners commented:

> *FLLJ: I was raised to respect the people who are older than me, and I was also told that the older people are always right on every issue they raise. Because of that, I choose not to question my teacher.*
>
> *MLLO: I was brought up in a manner that requires me not to direct my dissatisfaction towards elders, I cannot even criticise my teacher at home.*
>
> *FLLN: The relationship I have with my teacher is just like the relationship I have with my parents. Since I was brought up in a way which requires me not to voice out my opinions and views when being challenged by an adult, I don't complain about my teacher to anyone.*

These responses indicate that the learners want to interact or have a relationship with their teachers but they are concerned that they are being disrespectful. On the contrary, one learner stated:

> *MLLG: I focus on the subject, not the teacher. Science is objective and logical. How I was raised does not depend on my learning in school.*

The researcher was not surprised at the response of this learner. Most learners have been influenced by Western culture and social media and therefore tend to voice their opinions when they feel that their rights have been disregarded.

Differences between home learning and school science learning

The learners were asked if they find any differences between home learning and school science learning. Their responses indicated overwhelming differences between home learning and school learning:

> *FLLL: My parents are open-minded, understanding and they communicated well at home. Teachers however, are stern, stubborn and do not want to reason with us as learners in the classroom.*

MLLM: At school you learn when you even do not want to, while at home sometimes parents are too busy to follow you everywhere so they just chill and let you live alone.

MLLA: At home, I am likely to recall whatever I learnt from closer relations, whilst in school, you are forced to learn even when you are not willing to.

FLLF: My parents understand the kind of person I am and they address my issues well, yet teachers do not connect with your character and judge on academic works.

Although a majority of the learners indicated that they find differences between home learning and school science learning, in contrast, a few learners commented that they did not find any differences between school science learning and home learning. One learner indicated:

FLLD: No, there is no difference. In school I learn to become a better student by focusing on my school work. At home, I learn to be a better child.

The response from this learner indicates that he was taught how to behave in school and at home; the moral aspects of life being building self-confidence and discipline. Learning styles learners from typical traditional home backgrounds prefer

Culture has the capability to mode the ways in which its members receive process and act on information and experiences, thus influencing the manner in which they learn. When the learners were probed to specify the kind of learning style they prefer, most of them said that they mostly learn through verbal information, while some indicated that they rely heavily on non-verbal information to comprehend the full meaning of what is being deliberated. Two learners explained:

FLLB: I mostly learn from verbal stuff in a form of 'it is not right to do this or that'; 'always be on the lookout for people in need and assist them in whatever way you can'; 'show appreciation by saying thank you'; etc.

MLLE: I often learn at home from verbal information in the form of instructions. My parents will instruct me as what to do and what not to do.

The learners' responses show that the dominating learning style preference in their home backgrounds was a verbal learning style. Most of the learners confirmed this when responding to the interview questions. On the other hand, a few indicated that they learn

mostly through non-verbal information in the form of gestures, imitation and visual enunciation:

> *MLLK: I mostly learn behaviour at home through imitation, particularly, when I am punished for a bad behaviour, I learn to retained such behaviour and never repeat it at all.*

> *FLLJ: I learn better when I observe things as they happen at home. My grandmother would often demonstrate to you a particular norm. For example, when you receive food or any item from someone, you must put your two hands together.*

Also evident in some of the responses was that most learners prefer a visual learning style and retain information well when they see a certain event happening.

Influence of learners' home cultural practices on their learning at school

When the learners were asked how their cultural beliefs and practices impact their learning at school, they commented on the fact that their cultural beliefs and practices have some impact on their learning at school:

> *FLLF: The way I learn at school is based on Western culture. Meanwhile, the way I learn at home is based on my own cultural principles, but I do not see much of a difference. This is because I learn a lot at home by listening and I do the same at school.*

> *MLLC: The things I learn at home do not contradict the things I learn at school. My culture influences me to do better and in school too, my teacher tells me to learn hard so I can become an important person in future.*

> *FLLH: In my culture, I am expected to respect adults and not to talk back to any adult in authority. When I am at school, I am also encouraged to respect all my teachers and listen to what they say and ask me to do.*

> *MLLI: Yes, the values I learn at home are what I apply when I am learning at school.*

Research (for example, Breytenbach, 2013) indicates that culture impacts conduct and thus it would seem likely that differences in the cultural dimensions of groups of people would lead to differences in their approaches to working and studying. This viewpoint was corroborated by the responses from the learners.

Influence of learners' home cultural practices on their learning in the physical sciences classroom

The learners were asked if their cultural practices have any influence on their learning of physical sciences. A common thread which was emphasised through most of the learners' responses was that they apply some of their cultural practices in the physical science classroom. The learners narrated:

> *FLLN: Yes, I believe you apply what you are taught at home in the classroom, especially, the moral or social aspect of life, for example, having the tendency to complete tasks given to you.*
>
> *MLLO: I apply some of my cultural practices at home in school, e.g. when talking to an adult, do not put your hand in your pocket. Respect for other people's beliefs and practices, and at school, there is a common practice which we all subject to.*
>
> *MLLA: Yes, because, in my culture, I learn to be observant all the time. In the science classroom, I also learn to be observant.*

This section reveals that learners rely heavily on verbal information received from adults in authority, basically in the form of directives, without questioning it. References were also made by the learners on learning from visual information, mostly through observation. One common trend identified from the learners' responses was that people should be accorded with respect, especially, adults. Showing appreciation and being grateful was one of the moral values that are handed down from generations. This section further finds an evidence of power-distance as learners rank their teacher highly regarding knowledge and authority vested in him/her. Although a majority of the learners indicated that they find differences between home learning and school science learning, in contrast, a few learners commented that they did not find any difference between school science learning and home learning. The section also finds that differences in the cultural dimensions of groups of people lead to difference approaches learning. A common thread which was emphasised through most of the learners' responses was that they apply some of their cultural practices in the physical science classrooms.

6.2 Results from the teachers' interviews

This section presents teachers' perceptions on how the different cultural practices of the

Xhosa people translate into learning style preferences among learners in Mthatha schools. The data generated revealed the extent to which teachers' perceptions affected classroom learning and teaching experiences. The ultimate assumption is that it is imperative that teachers reflect on how their perceptions influence how they interact with learners who are from culturally diverse backgrounds. The four teachers' perceptions on the concepts chosen for investigation in this study are presented and discussed. The results are organised and presented around categories and sub-themes on the concepts raised. Being thoughtful and valuing the group of diverse cultures and languages represented in their classrooms help teachers to adopt strategies for teaching science that encourage and support learner achievement. In other words, it is essential to know the learners as it is to know the subject matter.

Teachers' understanding of culture and its impact on their teaching

When the teachers were asked: "What is your understanding of culture?", their responses tended to coalesce around House et al.'s (2004) definition. The teachers narrated (pseudonyms have been used):

> *Mr Mvana: Culture is the way a cluster of people live. In the context of the school setting, it relates to how teachers and learners interact with one another during the lesson, the type of language they speak often constitute the culture of that particular school. Punctuality, commitment and hard work, regular attendance to school, discipline on the part of the learners, teachers, SMT, can constitute the culture of the school.*
>
> *Mrs Anane: Culture is the way of how people live, how people interact with one another in a community, their shared values, behaviours and norms of a particular community.*
>
> *Mrs George: Culture is the way of life of a group of people in a particular area, who share common beliefs, values, norms and behaviours.*
>
> *Mr Thobela: Culture is all about living together as a group, including the kind of food they eat, how they dress, their language and their values and beliefs.*

The teachers' responses demonstrated that they had a common empathetic of the meaning of culture. The teachers emphasised the beliefs, values and behaviours within a society and indicated that the values that are handed down to generation determine people's sense of right and wrong.

Impact of teachers' cultural backgrounds on teaching

When the teachers were asked about how their cultural backgrounds impact on their teaching, diverse explanations were given:

> *Mr Thobela: My teaching is impacted by my cultural background. This is because my cultural beliefs and their values have an impact on my teaching. Occasionally in the course of the lesson, I do tell my learners the moral values and beliefs of my culture that we should not depart from.*

> *Mrs George: Yes. Conceptual development in learners greatly depends on how effective I am, and how I relate to the learners. However, how I relate to learners is mostly cultural dependent.*

Mr Mvana and Mrs Anane concurred with the statements above:

> *Mr Mvana: Somehow, my cultural background has some impact on my teaching because; the way I was brought up is the same way I am teaching my learners how to learn in the classroom.*

> *Mrs Anane: Culture influences one's perception, one's way of doing things as well as direct sometimes one's way of thinking. I always mention that knowledge could be applied to the social and cultural activities of different people as well as mine.*

These responses clearly indicate that teachers' cultural backgrounds influence their teaching styles. Findings from the teachers' responses affirm the belief that teachers' teach the way they themselves prefer to learn. The teachers highlighted that their cultural values inevitably help to shape their views and therefore influence their teaching styles.

Teachers' perceptions on the relationship between culture and science

When the teachers were asked "Do you think there is a relationship between culture and science?" they gave diverse responses. One teacher commented that there is no difference between science and culture:

> *Mr Mvana: Science is part of culture, and how … science is done largely depends on the culture in which it is practised. Thus, science at school is built from the knowledge that one has from their culture. This is true because culture is always modified by science. Therefore, just as science evolves, so is culture.*

Mr Thobela concurred with the above point and said:

> *Science is the knowledge obtained by observation and testing of facts. In science, knowledge is acquired through empirical evidence. It involves collections, analysing, and interpretation of data in order to draw conclusions. In teaching science, language is used to communicate ideas to the learners. In teaching sciences, some objects and artefacts can be used to clarify ideas to the learners. The use of language and artefacts for knowledge transmission is culture, and therefore, I find no difference between culture and sciences.*

Two other teachers gave views indicating the difference between science and culture:

> *Mrs Anane: Science is the study of nature which is central on the use of logical reasoning to make self-sufficiently confirmable associations between data and information. In contrast, culture involves beliefs that are sometimes based on nothing or partial truth or fact. I therefore see a difference between science and culture. They are dissimilar.*

> *Mrs George: Science is the study of the natural surroundings in an organised mode through scientific processes which can be tested and verified. In contrast, culture is the beliefs and customs of a group of people living in a particular area. It is also about arrays of activities that people living in a specific societal group acquire and share with no independent verification.*

These responses from the two teachers show that they believe that there is a clear distinction between science and culture. This is in contrast to the views of Mr Mvana and Mr Thobela.

Teachers' conceptions about scientific knowledge being socially and culturally influenced

When teachers were asked about their views regarding where scientific knowledge comes from, they gave varied responses. They indicated that science is a portion of the society and has its own traditions:

> *Mrs George: Science is universally; and as such, ideas from science are affected by the cultural, social and political settings of the society. Therefore, society and culture determine when and how science is conducted at any particular time.*

> *Mr Thobela: Everything in science is part of life so social issues affect science directly; in reality, science aims to resolve societal and cultural problems. Most of the scientific*

knowledge is built up from the indigenous knowledge which is the social and cultural activities of the people.

Mr Mvana: Scientific knowledge comes from scientists through their interaction with nature. However, societal issues influence science in a way that scientists try to find a way in their social life and try to fix that problem using science.

Societal values can influence science; on the other hand, scientific knowledge can also influence societal values and beliefs. If a society holds a belief that when the gods/ancestors are angry with the community, they curse them by infecting them with diseases that result in the death of most people from the community. This particular phenomenon could be explained by the science community as an outbreak of communicable disease, often due to poor sanitation and overcrowding. This is a social problem which can be solved through immunisation (using scientific knowledge and research) against appeasing the gods.

Mrs Anane concurred:

Science is based on facts and scientific knowledge is universal and general, and is influence by social and cultural beliefs. This is because; science answers social problems. My cultural and societal practices and ideologies are often proven wrong by scientific knowledge. For example, in my culture, there is a belief that albinism is caused by a spell which was evoked on the mother as a result of her being mean to other people. In contrast, science explains albinism as a lack of a skin pigment due to mutations. This is evidence that scientific knowledge is not socially and culturally influenced.

Inokoba, Adebowale, and Perepreghabofa (2010) argued that science, as an exertion and phenomenon, is not perceived and functioned in a social and conservational blankness Rather, science is a societal phenomenon which is significantly predisposed by the cultural practices and world-views of the people, for instance, their social values, priorities, ideas, norms, ethics, perceptions of social reality and belief systems. Cultural values and expectations of the society regulate what and how science is coordinated, deduced and acknowledged.

Teachers' perceptions of culturally relevant science teaching

The theme is categorised into: (1) responses that gave meaning of culturally relevant science teaching; and (2) responses that described teachers' perceptions of culturally relevant science teaching. According to Aikenhead (1980), the dominant cultural setting or the world-view of

any society controls, to a large extent, the progression of both scientific knowledge and technology and as well as how scientific believed and practices are prioritised.

The two categories of the teachers' perceptions and practices of culturally appropriate science teaching are described below:

The meaning of culturally relevant science teaching

When the teachers were asked about their thought on culturally relevant science teaching, their responses indicated a clear understanding of this topic. Most of the teachers believe that culturally relevant science teaching is a way of incorporating cultural values, norms, beliefs and relevant cultural practices into the science classroom teaching. Some of the teachers explained:

> *Mrs George: Culturally relevant science teaching is a way of incorporating aspects of culture in science teaching in order to honour the value of indigenous knowledge systems.*

> *Mr Thobela: I believe culturally relevant science teaching is a method of teaching science with the due thoughtfulness of culture in mind. In this way, the cultural richness can be fully felt.*

Other teachers also associated culturally relevant science teaching with cultural traditions, norms, history and beliefs. One teacher narrated:

> *Mrs Anane: In my view, I think culturally relevant science teaching encompasses aspects of the classroom practices that are relevant and correlated with the cultural desires and practices of the learners. Thus, it focuses primarily on considering cultural desires of the learners and designing instructions such that it incorporates cultural values, beliefs and norms of the society.*

A teacher clearly indicated in his response the need to recognise and respect traditional beliefs by incorporating stories and traditions in science teaching:

> *Mr Mvana: This is an aspect of science teaching where science teachers include stories in a form of folklores in the science lessons. This, I hope, will stimulate learners' curiosity in the subject and inspire them to learn and get more from sciences.*

A common factor that the teachers seemed to imply in their responses was the inclusion of

some elements of culture in the science lessons. The participants' responses were in line with the definition by Ladson-Billings (1999) who stated that culturally relevant science teaching is a form of instructional approach that incorporates cultural characteristics in the lesson to ease students' intellectual, social, emotional, and political development. In addition, Ford (2010 as cited in Mette, Nieuwenhuizen & Hvidston, 2016) states,

> "When we are responsive, we feel an obligation, a sense of urgency, to address a need … so that students experience success. When teachers are culturally responsive, they are student-centered; they eliminate barriers to learning and achievement and, thereby, open doors for culturally different students to reach their potential … [when culturally responsive] teachers proactively and assertively work to understand, respect, and meet the needs of students who come from cultural backgrounds different from their own" (p. 50).

Teachers' perceptions of culturally relevant science teaching

When the teachers were asked about their perceptions of culturally relevant science teaching, they gave varied opinions. A common trend identified from the teachers' responses was the fact that, when teaching strategies are adjusted to cater for the learners' cultural backgrounds, learners' interest in the topic rises and their motivation also increases. Two teachers said:

> *Mrs George: I think culturally relevant science teaching is more effective in increasing our learners' achievement and attitude towards science.*

> *Mrs Anane: In my view, this approach can improve teachers' instructional strategies to enhance learners' understanding in science. This could therefore increase learners' achievement in the subject.*

The findings corroborate the view that instructive practices need to be modified (Prowse & Goddard, 2010) to suit the local contexts to improve science teaching at schools. Culturally relevant teaching has been shown as an effective strategy to improve learners' achievement at various academic grade levels and subject areas (Carter & Welner, 2013; Gorski, 2013).

One teacher was of the opinion that culturally relevant science teaching creates social relations among learners and hence promotes an encouraging environment necessary for learning:

> *Mr Mvana: In my view, culturally relevant teaching helps my learners to develop the*

necessary learning skills, and create a social relationship among each other to promote an apprising environment conducive to learning.

Kelly-Jackson and Jackson (2011) reveal that culturally relevant teaching helps learners to develop the necessary learning skills and that teacher who uses this theory create a social relationship with their learners to promote a safe and nurturing environment inclusive to learning. Another teacher reflected:

Mr Thobela: These strategies of teaching really connect learners' prior experience and knowledge to the live experiences of the classroom. This promotes learners' learning and increases their understanding and makes science come alive. It enables teachers to appreciate learners' backgrounds and see their diversity as a means of supports.

Using culture as a lens to change teaching/learning processes in the science classroom

When the teachers were asked: "How do you use culture as a lens to change the teaching/learning processes in your physical science classroom?" they gave varied responses on teaching approaches that teacher could be employed in the science classrooms to modify the teaching/learning process. A common trend identified in the teachers' responses was the idea of involving cultural activities in teaching and using case studies applicable to learners' culture in teaching science.

The respondents further mentioned that they approach the learning situation in the science classrooms by providing hands-on experiences for the learners. While hands-on is advocated as a positive approach to engage learners in the lesson, also motivates them to study sciences. Two teachers narrated:

Mr Mvana: I think understanding the diversity of the classroom is the first step in laying the foundation of teaching science, and further providing appropriate instructions that takes cognisance of learners' prior knowledge and prior preparations, and incorporating this in familiar hands-on activities that engage learners in the lesson.

Mrs George: I have a belief that if teachers consider the differences among learners and provide differentiated instructions that incorporate the learning styles of the learners, together with practical-oriented instructions, [it] will go a long way to engage learners in the lesson.

These teachers also recognised the significance of considering different learning styles and

learners' cultural backgrounds in the teaching/learning process.

Several references were also made to place-based teaching. The teachers interviewed emphasised the significance of using place as an instructive tool to help learners see science as being important. For most of these teachers, their communities were used as an extension of the classroom to explore science in the context of their place, but without explicit cultural connections. For example, one teacher stated:

> *Mrs Anane: I use simulations and analogies to explain magnetic effect of a current-carrying conductor. One such analogy is the magnetic field around a straight wire where a compass needle is placed near a straight current-carrying wire aligns itself so that it is directed at a tangent to a circle drawn around the wire*

Other teachers used examples of local events, research projects and field trips to highlight scientific concepts. One teacher narrated:

> *Mr Thobela: Sometimes, I situate my lessons in the learners' cultural context and show them how the lesson is applicable to their experiences.*

There were comments on the integration of traditional teaching styles into the instructional strategies. This implies including members of the community in the classroom discourse. A teacher commented that sometimes he invites elders from the community to share their knowledge and expertise when teaching concepts that are related to learners' cultural practices:

> *Mr Mvana: In most cases, I relate my teaching to their cultural background, making comparisons here and there. Giving examples related to their home culture. Sometimes too, I explain concepts in physical sciences in a form of a story, something they can relate to, then I use the same scenario to relate to the concept I am teaching about in the classroom, considering their learning style preferences.*

Another teacher concurred:

> *Mrs Anane: My learners' cultural beliefs and practices are finely embedded through informal education and experiences within their family and communities However If our schooling system is not responsive to these cultural practices and values, the educational impact may be devastating.*

Many teachers mentioned that they never used resources that are readily available in the community, community members, local language and customs to inform their science teaching.

Promoting cultural infusion in the science classroom

When the teachers were asked "What can be done to promote and implement cultural infusion in the science classroom?" the responses from the teachers varied. A common trend was the idea of doing scientific research which involves investigations related to the culture of the learners to familiarise them with the instructional practises. The teachers commented:

> *Mrs George: I think, as a teacher, it [is] deemed right to know learners' cultural background and embrace their culture and take interest in the way they conduct themselves, particularly the way they learn and infuse it in the teaching/learning processes.*

> *Mrs Anane: I can achieve cultural infusion in my science classroom by considering learners' identity in my instructional practices to promote academic success in my classroom.*

Two teachers made references to instructional methodologies which takes into consideration the learners' learning style in the teaching/learning processes:

> *Mrs George: As teachers, we should be flexible and adapt teaching practices considering learners' needs and cultural identities.*

> *Mr Mvana: By using relevant cultural phenomena in enhancing learners understanding of scientific concepts in the science classroom.*

Mr Thobela echoed Mrs George's sentiment and highlighted that differentiated instructions that relate to teachers' use of culturally congruent content and instructions that shows the distinctive cultural, scientific and related perceptions of the students could improve learner understanding thereby promoting cultural infusion in the classroom. The teachers were of the opinion that it is necessary to improve learners' self-worth and social and cultural identities. A teacher highlighted:

> *Mrs George: If we, as teachers, make learners know about their culture and hear it at school, they will feel better about their identities and what they can achieve as*

individuals.

From this response, it is evident that encouragement is vital as learners do not see themselves as capable and thus they will feel included when their cultural background is tied into the design and implementation of the science lessons.

6.3 Chapter summary

In this chapter, the results from the qualitative phase of the study was presented and discussed. The results gave answers to how the cultural backgrounds of learners translate into learning style preferences among high school learners and how teachers can implement culturally responsive teaching in their science classrooms, thus answering research question 2.

The results from the learners' and teachers' interviews revealed that learners' cultural backgrounds influence their learning and learning preferences. The teachers also highlighted that the values and behaviours within a society determine people's sense of right and wrong that are handed down over generations.

In conclusion,

- It was apparent from the learners' responses that they mostly learn at home through visual and verbal learning styles. This means that there is emphasis on visual and conceptual illustrations for processing information in a learning situation.

- A common trend identified from the learners' responses indicates adult should be accorded with respect and not to be interrogated. However, the basis of a healthy relationship is built as teachers take the opportunity to interact and learn from their learners.

- The science teachers believe that values, behaviours and norms are key elements of culture and, as such, are adopted by learners to foster them to be acceptable members of society.

- All the teachers agreed that their cultural backgrounds are influenced by the teachers' own teaching styles. This supports belief that teachers teach the way they themselves desire to learn.

- A common trend identified from the teachers indicated that, when teaching strategies are adjusted to cater for the learners' cultural backgrounds, learners' interest in the topic rises and their motivation also increases.

- The teachers also advocated for doing scientific research which involves investigations associated with the cultural background of the learners so that the instructional practises are familiar to them.

In sum, the learners' responses showed that their cultural backgrounds influence their learning style preferences and the teachers highlighted the need to use culturally congruent content and instructions that reveal the distinctive social, scientific and background perceptions of the learners to promote cultural infusion in the classroom teaching/learning processes.

In the next chapter, learners' and teachers' perceptions on learning style-based instructional strategies are presented and discussed.

CHAPTER SEVEN
LEARNERS' AND TEACHERS' PERCEPTIONS OF LEARNING STYLE-BASED INSTRUCTIONAL STRATEGIES

7.0 Introduction

The aim of this study was to develop and implement a learning style-based instructional strategy in physical science classrooms to improve learner performance in the subject. This chapter responds to two of the research questions:

(1) How can students' academic achievements in electricity and magnetism be explained by the use of learning style-based instructional strategies in the science classroom?

(2) What relationships (if any) exist between the teaching styles currently used by the teachers sampled for the study and the most common learning styles of their learners?

The aim of the chapter therefore is to present findings from the learners' and teachers' responses to the questions above. As regards the perspectives and opinions of respondents, some common features of learning style-based instructional strategies implemented in the sampled schools that helped to enhanced learners' achievement in the subject were identified.

7.1 Responses from the learners' interviews

The essential part of the open-ended response section was for learners to give a detailed account of their experiences with the learning style-based instructional strategies in their science lessons for the purpose of triangulation of data. The data from the interviews were reported verbatim to corroborate learners' responses from the quantitative data. Responses from the interview data are presented by theme. Full details of the interview responses are given in Appendix G.

How learners learn in the physical science classroom

In this category, learners were asked how they learn the most in the physical sciences classroom. A common trend identified from learners' responses indicates that they have different approaches to learning physical sciences in the science classroom:

MLLD: I learn better when the teacher teaches with examples in the form of diagrams.

FLLD: I learn best when the teacher uses diagrams in his lessons. Seeing those diagrams make me understand the concepts better.

FLLA: When a picture/drawing is shown, am motivated to learn.

MLLC: I learn most in the physical science classroom when the teacher explains science concepts with diagrams which give me the whole idea of what exactly the lesson is about. Actually, illustrations make me see what the teacher is talking about for me to grasp the meaning of what is being discussed on that particular topic in physics.

The learners specified a strong inclination to the use of diagrams in the science classrooms which make lessons easier to visualise. This is a clear indication that learners rely heavily on illustrations and pictorial diagrams as a learning strategy. This is evident that learners had different preferences when learning scientific concepts. This is a clear indication that a larger proportion of the sample has a preference for visualisation.

References were also made to the "hands-on" experiences, which is an indication of active learning. Learners master the information when they participate actively in the lesson. A common factor that learners apply when learning science is getting engaged in the teaching/learning process as showed by the following quotes:

FLLB: I understand better when the teacher does the demonstrations in the classroom; it gives me a better ideas of the topic under discussion.

MLLC: I always prefer the teacher to make a practical example for me to understand the whole concept then I listen to the laws and find ways to answer the questions.

Three learners reaffirmed the above when they reported the following:

FLLA: I learn when I get involved in the learning process. I do so by asking questions for further explanation of fact, supported by examples.

MLLB: I learn through practical activities and demonstrations from the teacher.

MLLD: I learn most when the teacher includes me in the lesson, when I get the chance to explain some concept to my fellow classmates. That gives me the satisfaction to always pay attention to the teacher.

These responses from learners indicate that learners enjoyed the lesson when they are given

the opportunity to participate actively in the lesson. In short, learners rely heavily on constructivist learning as they get involved in the lesson; they create meaning of the instructional materials. This implies that learners have an inclination towards active/reflective learning styles.

Motivation to enhance their learning in the physical sciences classroom

Most of the learners who responded to the question on how they were motivated to learn better in the physical sciences classroom, said that they were motivated to learn physical sciences since they now understand science concepts much more clearly than previously. Typically, they argued that:

> *FLLD: I am motivated now that my teacher teaches in the same way as I learn. It has made me realise the way that I would understand physical science more by using the learning style strategies by the teacher.*

The respondents also mentioned that they are motivated to learn physical sciences now that the teacher involves them in the lessons:

> *MLLB: I am now motivated to learn physical science since the teacher involves us in the lessons and also he demonstrates the lessons and uses visual things like objects that we see and drawing.*

> *MLLA: I am motivated to learn physical sciences since I now understand science concepts much more clearly than previously.*

Several references were made to differentiate learning in which the teacher uses a range of teaching methods to accommodate diverse learners in classroom:

> *FLLD: I am motivated to work extra hard in physical science due to the fact that the teacher uses varied teaching methods which make the class to be active.*

> *FLLC: My interest in the subject has stirred up and I am motivated to revise and practise physical sciences all day ever since my teacher started using different teaching styles.*

One reference was made to cooperative learning in which learners come together to work in small groups to complete a given task. Feedback is often given by the teacher. A learner commented:

MLLP: Prompt feedback from my teacher motivates me to work extra hard in physical sciences and also having the opportunity to work with other learners in groups to complete a assignment inspires me to work hard.

The interview responses revealed that there was congruence in learners' responses. Most learners shared the view that they are motivated to learn better in the physical sciences classroom since the teacher used varied instructional strategies that have impacted positively in their learning and achievement. One learner noted:

MLLB: I get motivated to learn better in physical science classroom when I do get what the teacher is trying to say, that is as soon as I have a clue of whatever I was being taught. I also get motivated through practise, either alone or with my fellow classmates, because that makes me see things a bit easier.

Many learners indicated that working in groups was fun as they develop their own ideas, share responsibilities and work together. This has motivated them to work more in physical sciences.

The things that detract learners from doing well in physical science lessons

The learners were asked about the things that prevent them from doing well in the physical sciences lessons. A commonality which was emphasised through most of the learners' responses was that they liked making noise in the classroom in the presence of the teacher, particularly when the teacher is doing all the talking and learners are just listening. They get bored and they start making a noise. This implies that the learners do not like getting information that is heard or spoken (teacher centred teaching strategy) as this teaching method makes learners passive and unable to participate fully in the lesson. Inconsiderable number of learners narrated:

MLLC: Noise in class and so much notes and less diagrams or pictures weaken my progression.

MLLA: Chatting with my friends when the teacher is doing all the talking weakens me.

On the other hand, a few learners indicated that they get frustrated when other learners understand the science concepts and they do not understand, according to one learner:

FLLD: I get frustrated when other learners understand the topic and I am the only one

who's left behind. Sometimes, I get discouraged when the teacher is too fast for me.

References were also made about behaviour by the teacher and peers that creates a negative learning environment affecting learners' self-esteem:

FLLO: First of all, as an individual, I lack self-confidence. I fail to ask where I didn't understand even when the teacher is asking a person who didn't understand, I just keep quiet and get scared to say I am the one because I am afraid what the others will say if I show myself that I did not understand and but now I recognise that's one of the reasons that weakens me from doing well in my physical sciences lessons.

The responses from the learners indicate that, when teacher's instruction is not aligned with learners' learning styles, learners' get bored or get discouraged and may not perform well in class or even drop out of school.

In sum, the analysis of the data on things which detract learners from doing well in physical sciences showed that noise in the classroom affects them. Some learners made references to teachers moving too fast through the lesson and giving poor explanations of the concepts. In addition, learners' responses showed that they did not enjoy classes with teachers who created a negative learning environment by being judgemental and unsupportive, and allow peers to mock them when they answer a question incorrectly.

Physical science learning experiences with the implementation of learning style-based instructional strategies

When the learners were asked about their experiences with the learning style-based instructions, their responses indicated overwhelmingly that learning style-based instructions was very exciting, engaging and understandable. Two learners specifically claimed:

MLLL: Learning physical sciences through the use of hands-on activities and models is useful and helped me to grasp the science concepts easily.

FLLK: My marks have really improved since the introduction to this style of teaching. Presenting the lesson the way I learned made the lesson more easily understandable for me.

A common factor which was emphasised through most of the learners' responses was that they developed a strong liking for hands-on activities. They emphasised that hands-on

activities engaged them in the teaching/learning process. One learner stated:

> *FLLJ: Hands-on activities are very engaging as we work together; trying to develop our own thoughts and construct our own findings to solve a scientific problem. This makes science so real and understandable.*

Many learners indicated that they developed their own ideas from the teachers' instructions that required of them to reflect on their work. One learner narrated:

> *MLLF: This method of teaching gives us a broader perspective on the lesson, as the teacher engages us in the lesson.*

In all, having established a countless of responses pertaining to learners' experiences of learning style-based instructions, it could be deduced from learners' responses that learning style-based instructions are engaging and make science interesting and understandable for the learners.

The kind of instructional approaches that worked in the classroom

The learners were asked what kinds of learning style-based instructional strategies worked best for them in the physical sciences classroom. A commonality that was emphasised through most of the learners' answers was that they enjoyed teachers elaborated on the science concepts by utilising different instructional strategies, for instance, the use of charts, illustrations and, gave comprehensive descriptions and good examples and make certain that they understood the concepts he taught them. One learner wrote:

> *MLLB: I like science teachers who demonstration the lesson to explain concepts in front of the class. I found this helped me understand better.*

There were comments made on group work as style-based instructional strategy when studying physical science. Some learners indicated that they liked science teachers who give tasks on work done in class as a group and assigned responsibilities to group members. One learner narrated:

> *FLLE: Learning in groups is very exciting. We shared ideas. Sharing ideas makes me understand and remember what we did in the classroom better. I did not feel bored as I used to do before.*

Mention was also made of active learning. Many learners indicated that they took the initiative to be involved in the lesson and developed a deep understanding of the subject. Comments were also made about teaching styles that facilitated practical activities. Two learners stated:

> *MLLD: I like teachers who take time to let learners experience the teaching/learning process by involving us in practical activities in the classroom or in the laboratory, thereby sharing knowledge as we undertake the activity.*
>
> *FLLA: Practical activities are fun. It makes us relate science to real life situations. Also during practical activities, we are able to work together with our peers to communicate our findings.*

This indicated that the learners wanted to interact with the teacher when trying to understand problem areas in sciences. The teacher would then be able to help them improve their current performance through the sharing of their knowledge with the learners thus supporting them to develop better insight into sciences.

The kinds of instructional strategies which did not work in the physical science class

When the learners were asked about the kinds of instructional strategies which did not work in the science lesson, their responses showed the following instructional strategies:

- Unclear explanations and explanations given that confuse the learners.
- Moving too fast through the work before the learners can understand the work.
- Boring teachers who talk continuously in a monotonous tone and keep reading the same material.

These responses from the learners indicated the differences in learners' learning styles. Learners who are visual would be bored when the teacher explains major concepts in the science classroom verbally. Sequential learners would be bored if the teacher jumps from subject to subject in the sciences classroom.

The influence of learning style-based instructional strategies on learners' interest and motivation in physical sciences

This theme describes the influence learning style-based instructional strategies have on learner interest and motivation in science. Having established a myriad of responses, pertaining to the influence of learning style-based instructions, a closer examination of the responses was done. The responses substantiated the inference that the participants assigned responses based on interest and motivation categorically. Some learners believed that the use of the learning style-based instructional strategies and instructions have stimulated their interest in sciences as learning becomes more understandable. Typically, they argued that:

> *FLLB: Learning style-based instruction has impacted on my interest because the teacher uses different methods of teaching which have increased my interest in physical science. I do enjoy learning science all day.*
>
> *MLLC: When the teacher uses illustrations and diagrams to explain scientific concepts, it makes me to understand the topic far better.*
>
> *FLLD: When there are diagrams and examples, I understand the teacher's lesson better and my interest is elevated. In other words, this teaching style has increased my interest and understanding [in] the way I learn.*
>
> *MLLB: Learning style-based instructional strategies have positive impact on my interest. It has aroused my interest in the subject and I enjoy each lesson in physical sciences nowadays due to the different methods used by my science teacher.*

Some of the respondents limited the use of the learning style-based instructional strategies to motivation. This group believed that the use of these strategies in the lesson has inspired them to put in much effort in the subject.

> *FLLA: Learning style-based instructions have motivated me in achieving the highest level which is level 7 instead of level 5 which I used to achieve. Learning style-based instructions gave me that enthusiasm to keep finding questions and come up with solutions on my own. This instructional strategy also made me understand lessons and that has boosted my performance.*
>
> *MLLD: This strategy clearly shows me what I can understand, for example, by doing things practically in the laboratory and giving pictures so that I can see what the teacher*

is talking about.

FLLC: I have now seen that physical science is not that much of a bad subject. This program has made me determined into pursuing a career that is in the focus on physical sciences at the highest level.

The influence of learning style-based instructional strategies on learners' interest, motivation and achievement in physical sciences

This theme focused on learners' responses on their personal perception of the influence of style-based instructions on their learner performance. A number the respondents believed that their academic performance in the subject has improved since the introduction of the learning style-based instructions:

MLLA: Learning style-based instructions have given me a chance to gain conceptual understanding of the topics that were deliberated and make me feel the class and get something into my mind and become involved in the lessons, as my performance improves drastically.

MLLC: I am motivated to learn more and work extra hard as my performance is improving.

FLLD: It has only been impacted in a positive way because my results are better.

FLLC: My performance in the subject has been better, as am able to work more in physical science concepts.

Personal perception of the influence of learning style based instructional strategies on learners' ability in physical sciences

This theme focused on learners' responses on their personal perception of the influence of style-based instructional approaches on their ability in physical science. Most of the learners contended that they now find the subject enjoyable; they are capable of doing more as they see that the subject is interesting and they have been able to improve upon their performance in the subject. Typically, they argued that:

FLLD: I am now capable of doing more in physical science lessons. I get involved in the lesson and interact with my classmates and sometimes act as a leader in group activities.

FLLA: My performance has improved drastically in the subject and I no longer see

physical sciences as a difficult subject but as any other subjects like English. I now recognise that physics is not a challenging subject at all.

MLLC: It has improved my level of understanding in physical sciences. Since we as learners have been introduced to different methods of teaching which has increased our understanding in the subject as I see the subject as easier than before.

MLLB: I am doing well in physical sciences and my personal perception towards the subject has changed. I no longer see the subject to be difficult, but easy and fun when working with others on an activity.

There were comments on the satisfaction that the subject provides for learners. Many learners indicated that the subject has given them the satisfaction that physical sciences is just like any other subjects and it is not as difficult as they thought it was. Two learners stated:

FLLD: Very impressive, as I know now that engaging in activities in science lessons has changed my initial perception of physical science as a difficult subject. I now do so well in the subject.

MLLB: I now see physical sciences as an interesting subject. Working together in groups, the teacher used different methods which have made us love the subject, as we do far better now. This has given me much satisfaction in studying physical sciences.

Mention was also made that physical sciences is not a difficult subject to comprehend. A learner mentioned that he is able to solve science problems himself and his performance has also improved drastically.

Influence of learning style-based instructional strategies on perceptions of physical sciences as a subject

This section highlights on the learners' views of the impact of style-based instructional strategies on physical science as a subject. A commonality that was emphasised through most of the learners' responses was that they liked physical science as they see it as interesting and enjoyable. The learners narrated:

MLLK: It has improved my level of understanding physical sciences, since us as learners have been introduced to the current style-based instructional strategies.

MLLL: Learning style-based instructional strategies gave me a satisfaction of the fact

that physical science is just a subject as other subjects and it is not difficult as I thought it was.

FLLM: This strategy has assisted me to the point that my personal perception as seeing the subject to be difficult has disregarded.

FLLP: I no longer find the subject as less appealing, but have seen the subject to be fun as I enjoy my science lessons recently.

There were comments made by the learners about their change in attitude towards the subject. Some learners stated that their attitudes towards science as a difficult subject have changed. The learning style-based instructional strategies have helped them to the extent that they no longer see the subject as difficult rather that they enjoy studying it every day. One learner enthusiastically stated:

MLLO: With the kind of teaching I am experiencing now, my attitude towards the subject has drastically changed. I am now much [more] involved in the lesson than before. Science makes me feel good about myself. I would enjoy being a scientist now that I am enjoying science lessons.

A number of learners categorically mentioned that physical science is easier because of the strategies that their teacher now uses. They explained that they now get the chance to voice their feelings as they take part in the lessons. In addition, they now realise that physical science is better than they thought it was. The learning style-based instructions have made learners realise that they do not hate the subject but they can study and practice it to achieve higher marks.

7.2 Physical sciences instructional material that influenced learner performance

This theme was concerned with the type and nature of the learning style-based instructional strategies which were characterised by their form of organisation and presentation. This theme encompasses categories such as practical activities, conceptual and theoretical, diagrammatic illustrations and textual explanations.

Characteristics of practical activities of instructional materials that impact learner performance

Respondents described the characteristics of practical activities that influence their

achievements in the physical sciences, they gave a myriad of responses. The respondents contended that they learn much better when taught through practical activities. They gave the following justifications:

> *FLLJ: learning through practical activities are long lasting and also a basis to understand physical sciences concepts. Practice based teaching of science can make more successful than theoretical explanations.*

> *MLLC: Because of the fact that, if I learned things through the help of laboratory (practical work), it would be easy for me to remember and perform well.*

While for many learners there was congruency between the views they expressed in the interview and their responses to related items, some learners gave contradictory responses. Two learners believed that practical activities are more related to real life and, as such, they make science activities relevant and make science come to life. Specifically, two learners commented:

> *MLLD: Practical activities are much easier because when we are doing practical activities, we do things that are common or we know we do things we perceive and experience and feel it.*

> *FLLC: Practical activities are the best approaches to physics and are easier to explain the whole science experiments processes that we apply and consider which are more visual and visible to me and bring science to life.*

However, many learners share the view that practical activities help them to grasp the concepts and improve their marks. Practical activities have broadened their understanding about the topics in electricity and magnetism and have also enhanced their knowledge of science concepts. Typically they indicated that:

> *MLLG: Practical activities have improved my understanding since I now get the full grasp of the science concept.*

> *MLLH: Practical activities are helpful to me as I get to understand science concepts, clear understanding and help improve my marks.*

> *FLLI: Practical activities are very helpful as they assist me to remember things that my teacher told me in class.*

MLLD: Practical activities are more reasonable and give clear understanding of what the teacher talked about in the classroom.

PLLB: Practical activities influence my performance in a way that when we do practical at school, most of the times I do feel involved and it enables me to remember more and motivates me to do more in physical sciences.

Most of the learners appeared to directly draw upon their experiences in the practical activities by saying:

MLLA: This is helpful as it makes learners get involved in the lessons and working in groups with fellow peers is just amazing.

FLLC: Practical activities are the best way to understand a topic, as learners try concepts hands-on in real situations, thus making science come alive.

Nature of instructional materials that characterised conceptual and theoretical explanations of physical sciences

When asked about the instructional material that improved their performance, which is characterised by the emphasis on conceptual and theoretical explanations, some learners responded by saying that they prefer learning concepts and theories to practical activities through instructional materials which could give adequate explanations. Some of the justifications of their choice were:

MLLA: Teaching theories and concepts helps to understand practical works. Therefore, I prefer first to learn theories and concepts, and then I can perform the practical aspect to confirm or refute my earlier assumptions.

FLLB: Conceptual explanations also improve my understanding on scientific facts. Although it is different. it also improves understanding of facts. Practical activities add value to the theoretical concepts through explanatory presentations; therefore it improves my understanding of science concepts.

FLLC: The teacher used conceptual and theoretical explanations of science to relate concepts to reality, something related to our daily lives that we see it every time, it helps me a lot.

MLLD: Since my teacher taught these concepts in detail, I learned more and it helped me

for my current performance and also they help me to relate theory to reality especially using formulae.

MLLA: One thing that helped me to understand physical sciences is explanatory presentations of science concepts and theories through words. Teaching theories and concepts helps to understand practical works. Therefore, I prefer first to learn theories and concepts through activities.

While, for many learners, there was congruency between the views they expressed in the interview and their responses, some learners gave differing responses. This implies that these learners prefer learning concepts and theories to practical activities through instructional materials which could give adequate explanations. Typically, they mentioned that:

MLLB: Concepts in physical sciences have their own laws and principles. Therefore, presenting the subject using words gets me confused, unless it is presented along with diagrams and illustrations.

FLLD: Because understanding the concepts first helped me a lot to understand their mathematical representations and their relationships can be easily understood from their diagrammatic representations, rather than textual.

MLLC: Textual and conceptual explanations together with practical activities help me to know what I will be expecting during examinations and how questions are asked, because I prefer to do practical activities to theoretical and conceptual explanations/representations, as they get me confused.

This is clear evidence that learners learn in diverse ways and desire diverse instructional materials.

Diagrammatic, model and mathematical representations of physical sciences concepts

A critical look at the responses from the learners showed that visual representation of instructional materials helped them to perform better. Visual representation of instructional materials refers to instructional materials which are characterised by diagrams, models and mathematical and symbolic representations. Some of their responses are presented as follows:

FLLB: This concept influences my performance positively because I am able to interpret diagrams and videos that am exposed to in class therefore I get excited. Diagrams are

used to explain concepts in sciences which make the concept much clearer to me.

MLLD: I always like it when the teacher uses models and diagrams in his teachings. Diagrams, models and mathematical representations of science concepts enhance our understanding of the topic.

MLLC: Diagrams help a lot because I am able to see what the teacher is talking about and I don't forget it because of its diagrams. The use of diagrams in science assists me to find physics less challenging as it enhances my understanding of the subject.

A common factor that all the learners used to answer the question was that they remember what is shown to them. Two learners narrated:

FLLK: Mathematical, models and diagrammatic representations and expressions can present science concepts comprehensively. Therefore, these diagrams are very helpful in understanding science concepts, and remembering information received from the teacher.

MLLL: When there are diagrams and models used when teaching, it makes it easier for me to easily understand and it makes it easier for me to study because I will remember the diagrams and use them to solve mathematical questions.

There were comments on diagrammatic representations which induce learners' understanding and stimulate the lesson in such a way that learners are focused on the lesson. Three learners commented:

MLLP: Diagrammatic representations induce our understanding and stimulate the lessons in a good way. Diagrams help me to see the image of the topic under discussion and see clearly what we are talking about.

FLLN: Diagrammatic representations make things easy because, when a teacher uses diagrams, it makes it easier for us to have a picture of what he/she is talking about. Even if am writing exams, I will remember those diagrams.

FLLM: Because once I have learned theory through mathematical representations, it is easy for me to give explanations through mathematical representations. Diagrams inspire me and make the lessons much clearly and easily to comprehend, because, when science is represented diagrammatically or mathematically, it helps me to understand easily.

Textual presentation of physical sciences

When learners were asked about the nature of instructional material characterised by the emphasis it gives on textual explanation and oral description for physical science concepts, their responses and justifications were:

> *MLLO: Textual or oral representation of physical science lesson by my teacher has motivated me to ask questions on the unit I find challenging to grasp. This has also enabled me to build self-confidence as I managed to answer questions in the classroom.*
>
> *FLLH: Textual emphasis on the lesson is much clearer as it enhances my understanding of the information from the teacher.*
>
> *MLLG: Textual explanations are very helpful when new topic is introduced in class. It helps to catch a grasp of the topic, picking up important points and explaining them to make those words easier by shortening the meanings but with a valid point even though they are short.*

It is evident from learners' responses that learners have different approaches to learning sciences. However, some learners gave contradictory views as they indicated that they find it difficult to remember textual information. This shows clearly that most learners in the science classroom are visual and find it difficult to process verbal information. Some of the learners gave the following comments:

> *FLLA: Textual explanations of scientific concepts make the lesson harder to grasp. This is for the reason that at times I don't understand what the teacher says and don't even have a picture of what she is talking about.*
>
> *MLLC: Sometimes, textual explanations help me to understand important information fast, find it difficult to understand certain topics taught when the teacher does all the talking.*
>
> *FLLE: I become passive because there is no mechanism to ensure that I was intellectually engaged with the material.*
>
> *MLLG: My attention wanes quickly after 15 to 25 minutes and I tend to forget information quickly.*
>
> *PLLG: Textual representations of explanations are difficult to understand compared to*

diagrammatic or mathematical representations.

The essential characteristics of physical sciences instructional materials

Learners were asked to indicate from the physical sciences teaching/learning materials, such as textbooks and computer simulations, what they consider the most helpful for their current performance in physical science. In response to this question, learners listed and described the most helpful instructional materials in the order of: practical work, computer simulations, projectors, demonstrations, charts, models, pictures, textbooks and study guides. References were made about practical activities as the most helpful nature of instructional material:

> *MLLC: Laboratory work is the most helpful instructional material, because it helps to observe the chemical changes and occurrences. I therefore prefer to learn physical science through practical work.*

> *MLLA: Practical activities/work and teaching aids by teacher are relatively more productive than others. In laboratory based-learning, learners take part in the lesson which to make me remember the concepts all the time.*

> *FLLK: Laboratory work helps to realize (prove) what has been taught theoretically in the classroom. Therefore, we can be easily convinced. As a result, practical work can be useful to understand science concepts.*

Views from the learners showed that laboratory work relates to the extent of exposure to science process skills since learners indicated that practical activities prove theories taught in the classrooms, supporting learners to understand chemical concepts and theories. However, mention was made about the helpful nature of charts, models and projectors as instructional materials. Learners indicated that the charts, models and projectors as teachers' aids present learning experiences in pictorial forms. These teaching aids support instructions which are long lasting. The learners made the following comments regarding the uses of teaching aids:

> *FLLK: Teaching aids give more emphasis to oral explanations by the teacher.*

> *MLLM: Teaching aids emphasised symbolic representations of scientific concepts and phenomena which aid my understanding of these concepts.*

> *FLLL: Teaching aids are very useful in the lesson as it emphasises the understanding of major science concepts.*

Some learners made reference to the helpful nature of demonstrations as instructional material. Learners indicated that they participated in a critical evaluation of procedures during class demonstrations. The learners explained:

> *MLLG: The teacher's demonstration comes with explanations which help us to make predictions and record our observations.*

> *FLLD: Demonstration makes lesson easy to understand and it involves various senses to make learning permanent.*

> *MLLC: This method of teaching develops our interest in the learning and motivates us as we actively participate in the lesson. The discussions that follow after the demonstration also encourage elaboration of concepts in our own words and help to promote an awareness of our own thinking process.*

From these responses, it is evident that demonstration is an essential teaching approach which is typically used to introduce a new skills or concepts References were also made to the helpful nature of group work as an instructional material. Learners felt that group work was exciting as they shared ideas and constructed their own ideas to reflect on their work. Two learners said:

> *MLLA: We are given broader perspective of the work to do in groups and develop our own ideas to solve the problems at hand.*

> *FLLB: As we work in groups, we assisted each other which build our self-confidence and now I am able to discuss freely with other learners in my class, since I freely get along with the members of my group.*

Another learner reaffirmed the above when she reported the following:

> *FLLE: I liked this type of teaching and learning because the teacher does not give the answer straight forward. He allows us to reflect and discuss the task as a group first. He challenges us on points and feeds us pointers which give us directions to build our arguments.*

Physical sciences instructional materials which are considered least helpful

Most learners indicated that they easily forget when they read from textbooks and other textual materials. Typically, they indicated that:

PLLD: I easily forget when I read text from the textbooks.

MLLA: Text books give too much theory, which I find difficult to comprehend.

MLLC: Tt is difficult to understand fully from the textual presentation and the diagrams in the textbooks. It is because, what has been presented diagrammatically in the text book, may be completely new to me.

These responses from the learners showed that most learners could not learn independently, unless their teacher explained the concepts in the textbooks.

Respondents' suggestions for the improvement of physical science teaching for effective learning

When questioned how the instruction of physics could be improved, learners were of the opinion that physics teachers should encouraged more positive interactions among peers and between learners and the science teacher to boost learner confidence in the subject. Some of the suggestions they made included:

MLLB: I want my science teacher to be more patient to me and the rest of the class since most of us are very slow to grasp major concepts in sciences.

FLLA: I want my teacher to continue to build self-esteem and self confidence in the learners.

FLLB: Being more supportive.

MLLC: Ensuring the classes are more relaxed and dealing with lazy learners and demoting them if necessary.

The respondents also proposed that peer tutoring, be promoted and that learners are encouraged to use it.

7.3 Responses from the teachers' interviews

This section presents responses from the teachers' interview, which basically highlights teachers' perceptions of the learning style-based instructional materials used by the teachers during the intervention. Data pertaining to the study's fifth research question: *"How can learners' academic achievements in physical sciences be explained by the use of learning*

style-based instructional strategies in the physical science classroom?" were collected from the four teachers sampled for the experimental study. The presentation of teachers' responses is structured around the major themes that emerged and analysed using constant comparison analysis as discussed in Chapter Three. Six major themes emerged and are presented below.

Teachers' views on learning style-based instructional strategies

In this section, results are considered for teachers' understanding of the learning style-based instructional strategies. Interview data are reported verbatim. Three of the teachers gave responses which can be described as in agreement with their belief that learning style-based instructional strategies are adopted by teachers to teach learners according to how they learn. This is how they answered the question:

> *Mr Mvana: Learning style-based instructional strategies are methods .....I mean, teaching methods adopted by teachers and implemented according to how their learners learn.*
>
> *Mr Thobela: Learning style-based instructional strategies are the different ways by which the teacher teaches the learners according to the way the learners receive and process information from the teacher.*
>
> *Mrs George: Learning style-based instructional strategies are teaching methods by which the teachers adapt his teaching methodologies according to the ways learners learn.*
>
> *Mrs Anane: Learning style-based instructional strategy is an instructive approach to teaching, where teachers' instructions are tailored along learners' learning style preferences.*

These responses from the teachers indicated a clear understanding of learning style based-instructions.

Teachers views about the advantages of implementing learning style-based instructions

The focus of this section centres on teachers' views on the about the benefits of implementing learning style-based instructions in the science classroom. Many of the responses recorded focused on creating science lessons that are interesting to help them to learn science. One teacher mentioned:

Mr Mvana: This teaching strategy implemented enhances learner interest in physical sciences which enhanced their retention in the subject.

Some teachers believed that learning style-based instructional strategies improve learners' achievements in the subject. They indicated:

Mrs George: Implementing learning style-based instructions leads to learners' improvement in their achievement in physical sciences and also made science a good learning experience for all the learners.

Mrs Anane: Honestly, when I began implementing learning style based instructional strategy in my science classroom; it has encouraged learners to become participants in the lessons. Not one person sleeps in the class and no one complains of the subject being difficult.

Mr Thobela: Obviously, the implementation of the learning style-based instructions in my classroom has led to increased performance among my learners, since all the learners in the classroom were catered for during the teaching/learning process. This made them understood the concepts and therefore achieved in the test.

There was a common trend in the teachers' responses of engaging learners of diverse learning styles in the science classrooms. Responses from the teachers indicated that intensifying the utilisation of range of teaching styles is not to be imposed but should be introduced gradually into the classroom. Assisting learners to identify their learning styles and acknowledging their differences will augment their experiences and diversity to their scientific world.

The teachers explained:

Mr Thobela: The learning style-based instruction equips learners to work as a team; pull ideas together, below average and average learners are helped by the high achieving learners within the group.

Mrs George: Implementing learners' learning style-based instructions in the classroom helped the teacher to implement differentiated instruction. It helped the teacher to have systematic lessons where all learners were catered for and no one was left out in the process.

Mr Mvana: The putting into practice of learning style-based instructions was a very good

concept because different learners were able to receive the information in different ways, which made the learners to be more involved in the lessons. This increased their participation and engagement in the lesson.

Teachers' perceptions of the challenges of implementing learning style-based instructional strategies

When asked about teachers' views regarding the challenges of implementing learning style-based instructions in their science classrooms, the teachers expressed concern about the lack of necessary planning time, materials, resources and funding. Teachers narrated the challenges of implementing LS based instructions:

Mrs Anane: I am worried about the time and effort it took me to plan and implement learning style-based instructions. The one hour period allocated to me in this school is not enough to complete a lesson.

Mrs George: Implementing learning style-based instructional strategies require more planning, and more effort in preparation for each other lesson.

Mr Mvana: This teaching method requires more teacher effort. As such, I see it to be a burden on the part of me as I am already overloaded.

However, one teacher raised a concern regarding learners' behavioural problems and attitudes towards the implementation of learning style-based instructions.

He mentioned:

Mr Thobela: It may be difficult because of behaviour problems with regards to learners. Often, learners come from diverse backgrounds and providing instructions for everyone is challenging.

Resources needed to implement learning style-based instructional strategies

When teachers were asked to mention resources they will need in order to implement learning style-based instructions, they gave a myriad of responses, ranging from curricular materials to visual aids. Having available resources plays an important part in the implementation of instructional strategies to cater for the desires of all the learners with diverse learning style. Materials necessary for the successful implementation of learning style-based instructions include: teaching aids, curriculum materials, apparatus, reagents, textual resources, projectors,

computers, videos and audio recordings, visual aids, white and black boards and laboratories. The availability and implementation of these resources will yield positive attitudes which will reinforce learner achievement in physical sciences.

Some teachers specified that availability of resources, such as, curriculum materials, apparatus and equipments, and also provision of in-service training for staff would inspire them to use a diversity of teaching styles to accommodate learner differences in the classroom. Although teachers possess positive attitudes towards the implementation of a diversity of instructional strategies to meet diverse learning styles, they also require ongoing opportunities to build their understandings and abilities, as argued by NRC (1996). These enduring opportunities include attending professional development workshops, pursuing further studies and engaging in research. Each of such experiences would give teachers the chance to plan properly and work well with colleagues in order to accelerate change. For example, teachers could be given the prospect of engaging in collaborative research and share their research findings to a larger audience.

Challenges in implementing learning style-based instructional strategies

The teachers who were interviewed expressed concerns regarding the challenges they faced when implementing learning style-based instructional strategies. The teachers perceived that external factors, such as limitation of resources, planning time, staff development and attitude, influenced the teachers' ability to implement these diverse instructions to cater for different learning styles.

A lack of proper preparation constraint was a major concern for some teachers. These teachers view incorporating a variety of instructional strategies as simply adding more work to their busy days. The time required for preparation and delivery was a commonly cited impediment to implementing learning style-based instructions. One teacher commented:

> *Mr Mvana: Implementing learning style-based instructions is a challenge for teachers as it takes a lot of energy and time to prepare and deliver this type of instructional strategy in the science classroom.*

Class size emerged as another factor that impedes the implementation of learning style-based instructional strategy. Many of the teachers complained about having large classes consisting of 55-60 learners. Mr Thobela explained:

It's so difficult to have about 50 learners in one classroom and planning instructions for each one of them in the classroom.

Some teachers were also worried about class management as many sensed that learner misbehaviour could hamper the inclusion of a diversity of instructions. However, the teachers thought that many learners articulated behavioural problems owing to dullness or frustration that may results from the nature of instruction that is given. The teachers mostly used traditional lecture method and discussions as main approaches of instruction:

Mrs Anane: I see some learners getting bored if their learning styles are not catered for in the lesson.

However, some teachers also expressed concern about some learners not paying attention when assigned to groups. One teacher stated:

Mrs George: Usually, when I assigned learners to do a group activity, I often noticed some learners not paying much attention within the group. Not being active and attentive members within the group.

Another challenge faced by teachers in implementing this kind of learning-teaching style, was their inability to complete the syllabus on time. These teachers thought that the pacesetter is time bound and that this type of learning style takes time and effort to plan and prepare before implementing it in the classroom. Typically, they narrated:

Mrs Anane: Naturally, it is not easy to meet all the learners' learning needs in a particular lesson, and this posed a challenge in the implementation of learning style-based instructions in the physical science classrooms.

Mr Thobela: Grouping learners to learn and master given tasks, considering their learning styles, takes a lot of time in the classroom environment.

To address learner needs in the science classroom, teachers should employ different instructional methodologies. Though, it is not easy to modify instructions to the learning styles of each learner. However, what is necessary is that teachers' instructional methodologies during the lesson provide point of contact for learners with different learning styles. To retain a larger number of learners' interested in science, teachers should employ a teaching style that descends from several instructional approaches.

Support received from school when implementing the learning style-based instructional strategies in the physical science classroom

Teachers articulated the necessity for essential materials that play a part in implementation of wide-ranging instructions that cater for the diverse learners in the physics classroom. Armstrong (1994) and Dunn and Dunn (1979) suggested the use of; hands-on materials; videos; visual aids; and computer simulations. However, most schools do not have these types of facilities. Teachers should be given the chance to employ and improve upon these activities in their classrooms. Effective implementation with the essential materials may produce helpful approaches to support teachers to improve learner achievement in science.

> *Mr Thobela: The use of overhead projector (OHP) and the electronic board may facilitate the group-style approach.*

Employing these types of instructions in the physics classroom are the sole prerogatives of the teacher only if he/she can complete the syllabus on time. This is because implementation of these teaching approaches during the lesson in the classroom is time consuming. A teacher commented:

> *Mr Mvana: In my school, for example, there are many visual audio instruments which go a long way to help when teaching concepts that requires efforts and time to set all of these up and use them.*

Ways to improve learner achievement in the physics classroom

The teachers were asked about how they can boost learner success in physics. In reply, they gave a number of responses. A common trend in their responses was the necessity to align learners' learning styles to the teacher's teaching style to enhance learner performance in science. The quantitative study showed that when learners' learning styles were matched with the teacher's teacher styles, the learners performed better. This clearly suggests there is added value to implementing learning style-based instructions in the science classrooms to enhance learner performance. One teacher emphasised:

> *Mrs Anane: I think the most basic aspect of this is use of differentiated instructions to enhance learner performance in the subject. When teachers use varieties of teaching styles, complimenting each other and catering for all the different ways by which learners' learn, learner interest and motivation will increase, thereby increasing learner*

achievement in the subject.

Some teachers stressed the need to have resources to implement learning style-based instructions in the science classroom:

> *Mr Thobela: lack of teaching materials impede on our performance as teachers. If teaching materials are available in our schools, teachers would use them effectively to ensure quality teaching in the classrooms.*

Another teacher was of different view. She explained what should be done to enhance learner performance in science:

> *Mrs George: Give precedence to the means by which learners deal with situations, and emphasise the development of individuals, their emotional life and self-awareness. Sequence learning tasks and shaping behaviour, organise data, generate concepts and solve problems.*

Harmonising activities, by incorporating learning styles, assist learners to focus on their studies, to be inspired and to improve upon their performance. Learners might experience challengies at first when asked to do something that seems unusual to them, but they might embrace other learning styles, even if it is not that easy. At the end, the teacher improves upon their teaching and might as well help learners identify and develop their less dominant preferred learning styles.

Teachers' reflections on the short professional development intervention

The short professional development intervention employed in this study was informed by Warford's (2011) "zone of proximal teacher development" (p. 253), a feature of Vygotsky's (1978) social-constructivist view of zones of proximal development, which signifies the distance between what teachers can do on their own and a proximal level they might accomplish through structured, facilitated assistance from more capable others. In hypothesising such support, a three-day workshop was organised for the sampled teachers which was facilitated by the researcher (see section 3.8). The participants were interviewed to gain insights from their thoughts on the workshop and to know how this new knowledge might influence their future classroom practices.

The findings showed that, at the beginning of the workshop, two participants out of the four

teachers interviewed were unaware of the concept of learning styles and learning style-based instructions. Nevertheless, the two that were aware of it did not design instructions with learners' learning styles in mind. After the short professional intervention, there was a shift in teachers' understanding of designing instructions with learners' learning styles in mind and to teach according to learners' learning style preferences (four teachers observed). The following sentiments were expressed by participants:

> *Mrs George: I wish we could have more days for this intervention program so that I could learn more on the design of learning style-based instructions.*
>
> *Mr Thobela: I think we should extend this training for a week or so, so that we could learn more about designing learning style-based instructions.*

This corroborate with the findings from Herman, Clough and Olson (2013) that the levels of internalisation of new knowledge and practices increases with the extent of steady commitment. It can for that reason be anticipated that, as the teachers continue to commit to the training and evaluate their own practices as they carry on to implement learning style-based instructions in their various classrooms, they can anticipate higher levels of achievement among learners in physical sciences.

The results indicate that the teachers responded positively towards the workshop and establishing remarkable levels of appreciation of learning styles and learning style-based instructions. This was observed during the group presentations. However, Buma (2018) warns, such outcomes should be interpreted with care, being careful of the probable contrasts between the progressive workshop setting and their usual classroom environment. With regards to the group presentations, the teachers successfully used the materials provided at the beginning of the workshop to imitate what was demonstrated on Day 1 of the workshop. There was an indication of comprehensive preparation towards the presentation, together with well-designed lesson plans. Each group effectively introduced the lesson in such a way that arouses interest and efficiently assimilates the science content to the learners' sociocultural background and facilitating instructions that were learner-centred and based on learners' learning style preferences which have been revealed to promote effective learning outcomes (Keraro & Okere, 2009). The group presentations were successfully done which could also be attributed to the progressive understanding and appreciation of the theory of learning styles and learning style-based instructions and the utilisation of effective techniques of pedagogy.

It could hence be argued that the teachers' workshop equipped the teachers with knowledge about the design and implementation of learning style-based instructions in physical science teaching.

The teachers were of the opinion that the workshop was very educative and provided avenues for a better understanding of how such instruction could be effected at the school level. A teacher commented:

> *Mrs Anane: I enjoyed all the activities … our group presentation was very valuable and enlightening as it reports on awareness on the differences among learners in our classrooms. It was awareness training. I now know more on how to cater for the different learners in my science classroom.*

Productive learning was likely as the teachers worked in groups, making suggestions and sharing knowledge and learning enthusiastically from each other and particularly from the facilitator, which is significant of Warford's "zone of proximal teacher development" (Warford, 2011, p. 253).

The use of artistic methods and technology had perhaps the utmost insightful impact on the teachers during the workshop. Most teachers were astonished that many physics topics, which were mostly considered as abstract and difficult to get to, could be presented in exciting and stimulating ways, which accommodated diverse viewpoints. One participant said:

> *Mrs George: It is very stimulating and enlightened and got us to reason critically and articulated how one feels about being left behind.*

There was general agreement among participants that, regardless of the challenges facing science education in South Africa, a restructured approach to science teaching should be encouraged to equip science teachers with skills to make an effort to make science content more accessible and pleasant to learners through the implementation of learning style-based instructions.

7.4 The classroom observation results

The results of teachers' classroom practices are highlighted in this section, specifically, and the teachers' adaptions of learning style-based instructional methodology. The focus is on research question 3: "*What correlation exists between the teaching styles currently used by*

teachers in the four Mthatha schools and the most common learning style of their learners as determined by the index of learning styles?"

As discussed in section 3.5.5, direct classroom observations were conducted to determine whether teachers matched instructions to learners' learning styles and whether teachers implemented the learning style-based instructions in their classrooms. The classroom observation was done using the CCSSE classroom observation tool, which resulted in both quantitative (Likert scale) and qualitative (comments) data. See Appendix I.

Table 7.1 displays the quantitative results of the CCSSE form. The figures presented in Table 7.1 below represent the minimum and maximum of the participant scores in each CCSSE section. The researcher derived those values by summing each participant's sub-section scores in each section. The researcher subjected the participant section sums to descriptive statistical analysis using STATA (Integrated Statistical Software package for data analysis, management and graphics).

The participants scored the best marks in Section 2: Knowledge of Subject Matter and Section 5: Encouragement to Engage in Critical Thinking. Table 7.1 gives results for the researcher's ratings of the CCSSE data.

Table 7.1: Ratings for each teacher on each of the five CCSSE sections scores

Item #	Criteria	Ratings					Comments
		George	Mvana	Anane	Thobela	Billie	
A	To what extent did the teacher demonstrate the following behaviours?						
A1	Teacher started and ended class on time	1	1	1	1	1	All the five teachers started and ended the class on time
A2	Teacher was prepared to conduct class	1	1	1	1	1	All the five teachers were prepared to conduct the lesson
A3	Ensured students were engaged in the learning activities planned for the class	1	1	1	1	1	All the teachers engaged their learners in the classroom

	section						
A4	Noticed when students were not engaged and took action to involve the students in the class activity	1	1	1	1	1	All the teachers noticed when learners were not engaged and took action
A5	Clearly explained the learning objectives for the class session	1	1	1	1	2	All the five teachers explained the learning objectives for the class session
A6	Summarised the major points at the end of the lesson	1	1	1	1	1	All the teachers observed end lessons by summarising major points
B	To what extent did the teacher demonstrate the following behaviours?						
B1	Explained concepts clearly	1	1	1	1	1	All teachers explained concepts clearly with words
B2	Teacher gave "real-world" to illustrate concepts	1	1	2	1	3	Billie did not do this
B3	Responded adequately to student questions	1	1	1	1	2	Billie partially responded to learner questions
C	To what extent did the teacher demonstrate the following behaviours?						
C1	Spoke clearly and audibly	1	1	1	1	1	Evident in all the five teachers
C2	Showed enthusiasm for the subject matter and teaching	1	1	1	1	3	Billie did not show much enthusiasm
C3	Treated all students in an equitable manner	1	1	1	1	3	Billie did not treat all learners as equal
C4	Encouraged questions and student participation	1	1	1	1	3	Billie did not encourage learner participation
C5	Gave students an adequate amount of time to respond to questions	1	1	1	1	3	Evident in George, Mvana, Anane and Thobela classrooms
C6	Provided feedback that gave students direction for	1	1	1	1	3	Billie did not provide much feedback

	improvement						
C7	Interacted with individual students during the class section	1	1	1	1	4	Evident in all the four teachers classes except Billie's classroom
C8	Interacted with students working in small groups during the class	1	1	1	1	4	Billie did not do this
C9	Elicited feedback validation of students' understanding of the material	1	1	1	1	3	Evident in George, Mvana, Anane and Thobela classes
C10	Used techniques that reflect an awareness of different learning styles	1	1	1	1	4	Billie gave lee-way for this to happen in his classroom
C11	Appropriately used web-based resources, PowerPoint or other technological tools	1	1	1	1	4	Billie gave lee-way for this to happen in his classroom
C12	Encouraged or required students' engagement in and out of class activities related to the course	1	1	1	1	4	Billie's learners were limited and did not encourage learners' engagement in the school
D	What percentage of time was spent on each of the following instructional techniques?						
D1	Lecture	3	3	3	3	1	Evident in Billie's classroom
D2	Teacher-led discussion	3	3	3	3	1	Evident in Billie's classroom
D3	Teacher-student shared responsibility	1	1	1	1	4	Evident in George, Mvana, Anane and Thobela classes
D4	Student computer use	1	1	1	1	4	Not seen in Billie's classroom
D5	Small group activities	1	1	1	1	4	Not seen in Billie's classroom
D6	Student presentations	2	2	2	2	4	Not seen in Billie's classroom
D7	Hands-on practice	1	1	1	1	3	Hardly seen in Billie's classroom

D8	In-class writing	2	2	2	2	2	Partly seen in all the classrooms
D9	Performance	2	2	2	2	3	Partly seen in all the classrooms
D10	Experiential learning	1	1	1	1	4	Not seen in Billie classroom
D11	Assessment activities	1	1	1	1	3	Hardly seen in Billie's classroom
E	To what extent did the learning process designed by the teacher encourage students to engage in the following cognitive processes?						
E1	Memorising facts, ideas, methods so that they can be repeated in the same form	3	3	3	3	1	Billie's learners were memorising facts and methods so they could repeat in the same form
E2	Analysing the basic elements of an idea, experience or theory	1	1	1	1	3	Not evident in Billie's classroom
E3	Synthesising and organising of ideas, information and experiences in new ways	1	1	1	1	4	Not evident in Billie's classroom
E4	Judging value or soundness of information, arguments or methods	1	1	1	1	4	Not evident in Billie's classroom
E5	Applying theories or concepts to practical problems in new situations	1	1	1	1	3	Not evident in Billie's classroom
F	Overall, did the teacher create an engaging learning experience during the observed class session?	1	1	1	1	4	Not evident in Billie's classroom

The researcher's ratings presented in Table 7.1 above are also supported by comments which were treated as interview data. The scores from Table 7.1 were transformed into a bar graph, for the purposes of clarity and elaboration. As shown in the Figure 7.1, George, Anane, Thobela and Mvana had a total score of 37 each, implying that the nature of instruction

commonly practiced in the science classroom was aligned to the learners' learning style preferences. Billie's practices of matching teaching style to learners' learning style were low, with a higher score of 104. In all the five facets of each section, Billie scored the highest. Billie practiced teacher-centred instructional methodology that overwhelmed learners with information. The lowest scores indicate that the teacher matched instructions to learners' learning styles. The highest scores indicate unmatched instructions.

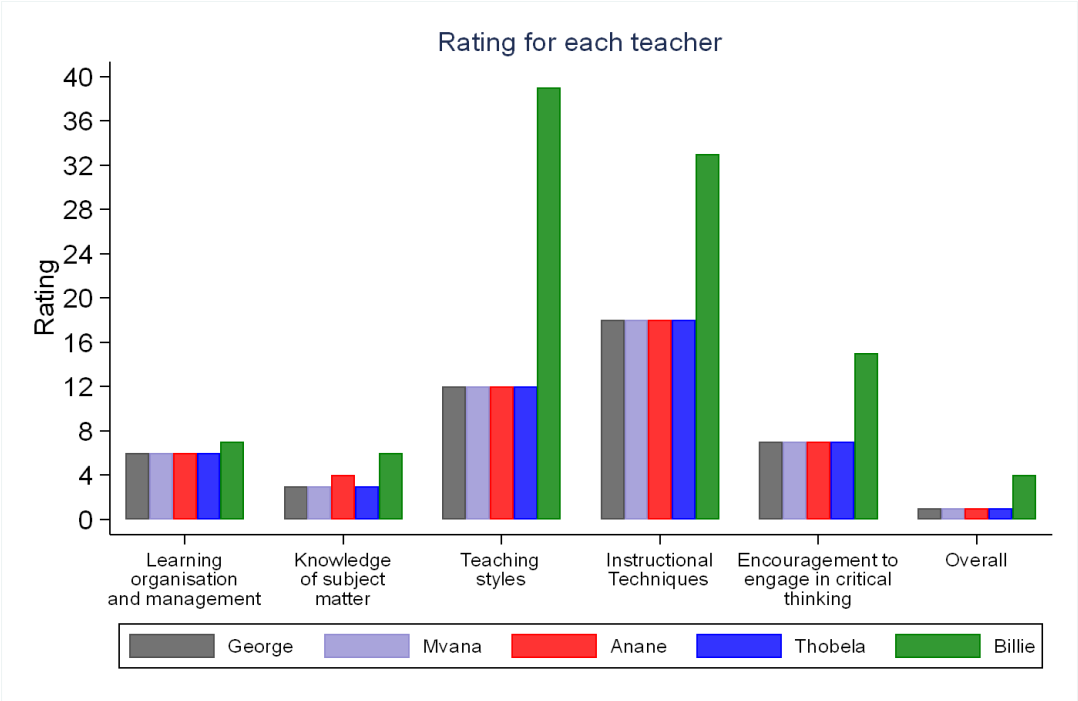


Figure 7.1: A graph showing the researcher's ratings on the teachers' adaption of instructional methodology

Table 7.2 shows CCSSE score analysis. The range denotes the smallest and largest scores possible in each section. Lower CCSSE scores on each section are considered indicative of more desirable teaching behaviours. From Table 7.2, it can be deduced that the widest variation was seen in Section C, Teaching Style, where a standard deviation of 12.07 occurred.

Table 7.2: CCSSE Score Analysis

Section	Range	Minimum	Maximum	Mean	Standard Deviation
A	6 – 30	6	7	6.2	0.45
B	3 – 15	3	6	3.8	1.30
C	12 – 60	12	39	17.4	12.07
D	11 – 55	18	33	21	6.70
E	5 – 25	7	15	8.6	3.58
F	1 – 5	1	4	1.6	1.34

As discussed in Table 7.2 above, there was consistency and generally good performance indicated in the observation tool. The four participants who were sampled to implement learning style-based instructions in their science classrooms scored the best possible marks in Sections B and E. The widest variation was seen in Section C, teaching style, where a standard deviation of 12.07 occurred. The lowest scores on the observation tool were considered indicative of more desirable teaching behaviours.

CCSSE Tool: Section C

The CCSSE section C has 12 items (see Appendix K). Therefore, the minimum possible score is 12 and the maximum possible score is 60. Because the items that make up each section are all positive in terms of desired teaching behaviours, lower scores in each section indicate better performances. As shown in Table 7.3 below, Section C scores of the study sample ranged from 12 to 39 with a mean of 17.4 and a standard deviation of 12.07. One participant scored in the highest (indicating the least diversity in teaching methodologies), which was impacted by ratings of 4 (not at all) on items C7, C8, C10, C11 and C12 (see Appendix M). The other four participants who matched teaching styles to learners' learning styles were all within one standard deviation of the mean.

Table 7.3: CCSSE Tool: Section C scores

Section C of the CCSSE					
Item	**George**	**Mvana**	**Anane**	**Thobela**	**Billie**
C1	1	1	1	1	1
C2	1	1	1	1	3
C3	1	1	1	1	3
C4	1	1	1	1	3
C5	1	1	1	1	3
C6	1	1	1	1	3
C7	1	1	1	1	4
C8	1	1	1	1	4
C9	1	1	1	1	3
C10	1	1	1	1	4
C11	1	1	1	1	4
C12	1	1	1	1	4
NOTE: Displayed teaching behaviours: completely = 1; adequate = 2; minimally = 3; not at all = 4; not applicable = 5					

CCSSE Tool: Section D

There were 11 items that constitute Section D of the CCSSE. As discussed in section 3.5.5, Section D uses a five-point scale to quantify the amount of class time that was devoted to particular teaching techniques. The observation of more than one teaching technique being used simultaneously may result in time totals in excess of 100%. Therefore, higher total scores indicate the use of fewer teaching methods and lower total scores indicate the use of more teaching methodologies. It is important to recognise that a heavy emphasis placed on 3 and 4 methods to the exclusion of all others could also result in a high total score. Of particular note was the fact that all five participants scored a two (40-74%) on item D8, the percentage of classroom time devoted to in-writing. However, because of the scale of construction of the CCSSE tool Section D, the minimum, maximum, mean, and standard deviations would not provide useful information.

Table 7.4: CCSSE Tool: Section D scores

Section D of the CCSSE					
Item	**George**	**Mvana**	**Anane**	**Thobela**	**Billie**
D1	3	3	3	3	1
D2	3	3	3	3	1
D3	1	1	1	1	4
D4	1	1	1	1	4
D5	1	1	1	1	4
D6	2	2	2	2	4
D7	1	1	1	1	3
D8	2	2	2	2	2
D9	2	2	2	2	3
D10	1	1	1	1	4
D11	1	1	1	1	3
NOTE: Displayed class time devoted to instructions: completely =1; adequate=2; minimally = 3; not at all= 4; not applicable = 5					

The researcher's ratings presented in Tables 7.1, 7.2, 7.3 and 7.4 are also supported by comments. Comments were analysed just like the interview data. The following predetermined themes emerged: extent of teacher demonstration of behaviours, illustration of concepts, and percentage of time spent on instructional techniques, design of learning process, and so forth.

Extent of teacher demonstration of behaviours

The analysis of the class observation indicates that, all the teachers started and ended the class on time. Teachers were prepared to conduct class and ensured learners were engaged in the learning activities planned for the class sections for each particular day. All the teachers noticed when learners were not engaged and took action to involve the learners in the class activities. These findings are in alignment with previous research showing that teacher support is related to strategy use (Paris & Newman, 1990) and that learners who noted that their teachers were supportive and cared about their success were more likely to be engaged in the classroom and perform well academically (Akey, 2006). Furthermore, all the teachers clearly explained the learning objectives to the class and summarised the major points at the end of the lesson. All teachers explained concepts clearly using words and gave real world examples to explain concept. Billie on the other hand did not give real world examples to emphasise the concepts and partially responded to learners questions. This resulted in learners' disengagement in the lesson. This finding is in line with the finding of Akey (2006) who showed that learners who do not feel confident in their ability to succeed are not likely to

attempt to do the work. Building learners confident is about assessing learners' weaknesses and strengths and developing ways to address them at developmentally appropriate yet rigorous levels.

Extent of teacher illustration of concepts

It was observed in the classrooms of the teachers for the experimental study that learners engagement in and out of class activities were related to the subject. The four teachers appropriately used web-based resources, PowerPoint or other technological tools and techniques to reflect an awareness of different learning styles. The teachers further elicited feedback validation of learners understanding of material, interacting with learners working in small groups during the class, and provided feedback that gave learners direction for improvement, and an adequate amount of time to respond to questions, that showed enthusiasm for the subject matter and teaching. Many studies have described aspects of classroom practices by the teacher which are related to effective classroom learning and learner outcomes (Brophy & Good, 1986; Wang, Haertel & Walberg, 1993). Close monitoring, adequate pacing and classroom management as well as clarity of presentation, well-structured lessons and informative and encouraging feedback have generally been shown to have a positive impact on learner achievement. However, this was not evident in Billie's classroom as he did not show much enthusiasm and did not encourage learner participation.

Percentage of time spent on instructional techniques

It was seen in Billie's classroom that the teacher spent more time lecturing and leading class discussions. However, teacher-learner shared responsibility was not evident in Billie's classroom since the teacher dominated the class all the time. This is typical of traditional teaching method. As highlighted in the introductory part of the study, Kulkarni and Klemmer (2012) noted that a severe deficiency in traditional teaching methods in the physical sciences classrooms resides in the fact that learners do not visualise the details of different science processes and they frequently fail to understand the most basic science concepts and phenomena. Thus learners are characterised as unreceptive to knowledge and therefore recourse to memorisation. However, with the changes taking place in South African basic educational institutions, increasing demands are being placed on learners for enhanced academic performance. Teachers are also accountable for the non-performance of their learners at the end of the year matric examinations. Therefore, there is the need to stress on

the importance of learning styles in the teaching and learning process.

On the other hand, teachers used for the experimental study utilised differentiated instructions in the classroom and spent more time providing learners opportunities which were recognised and utilised by the learners for effective outcome of the lesson goals. This finding corroborates with the findings of Weiss and Pasley (2004) which indicate that high quality instruction, aligned with content standards and uses instructional strategies to meet the academic needs of all learners is a key factor in promoting a culture of engagement and achievement in the classroom. With that said, teachers are noted to be the most influential in a learner's educational experience where they create a culture of achievement in the classroom by developing interactive and relevant lessons and activities to foster learners engagement in the learning environment.

Extent of learning process designed to encourage students to engage in cognitive processes?

Analysis of teachers' comments indicated that the four teachers who participated in the teacher workshop engaged learners in the basic elements of an idea, experience or theory synthesising and organising of ideas, information and experiences in new ways through hands on activities by applying theories or concepts to practical problems in new situations. In this way, the learner can be elevated to a higher level of understanding (Donald, Lazarus, & Lolwana, 2010). While Billie's learners were memorising facts and methods so they could repeat in the same form, the teachers used in the experimental study consistently encouraged learners to engage in critical thinking with the use of effective questioning in their classrooms. Kolb and Kolb (2005) recognize the importance of making meaning from experiences through conversation. Creating opportunities for conversation in the learning process allows students to reflect on and make meaning about experiences which improve learning (Kolb & Kolb, 2005). Van Rensburg (2002) argues that the use of learning style instruments can improve interaction for both students and teachers. This cannot be said about Billie who used one teaching strategy in his lessons and did not encourage any form of critical thinking in his classroom.

Overall teacher engagement of learning experience during the observed class session

Analysis of the sampled teachers' comments indicated they consistently matched instructional

methodologies to participants' common learning styles and provided them with immediate feedback. Matching teaching styles with learners' learning styles allows the teacher to use a more balanced teaching strategy, one which accommodates the different learning styles in the class (Felder & Brent, 2005; Litzinger, Lee, Wise & Felder, 2007). It is important that the teacher understands the learners' learning processes and consider a variety of approaches for each learning experience (Litzinger, Lee, Wise & Felder, 2007).

The findings show that learners' participation in the classroom discussions and activities increased because of the adaption of instructional methodology with their learning styles. Rochford (2004) argues that students who are taught through their learning styles become motivated; their learning improves and they achieve better academically. It was also found that the four teachers used for the experimental study consistently organised their learning and managed their classrooms effectively. They were also found to be on par with the subject knowledge matter and consistently matched teaching styles to learners' learning styles using different instructional techniques.

7.5 Chapter summary

Results from the direct classroom observation and learners and teachers interviews were presented in this chapter. The results gave answers to how teachers and learners perceive learning style-based instructional strategies and how often teachers practices matched instructions to learners' preferences of learning when teaching electricity and magnetism. Thus, answering research question 3.

Findings from the learners indicated overwhelmingly that learning style-based instructions was regarded as exciting, engaging and comprehensible. A common factor which was emphasised through most of the learners' responses was that learners developed a strong liking for hands-on activities. They emphasised that hands-on activities engaged them in the teaching/learning process. Many learners indicated that they developed their own ideas from the teachers' instructions that required them to reflect on their work.

There was a common trend in the teachers' responses to involve learners of diverse LS in the science classrooms. Responses from the teachers indicated that intensifying the selection of diverse instructions is not an abrupt, major shift, but more precisely, a gradual process that can be approached in incremental steps, introducing new methods one at a time. Drawing a

more diverse group of learners into science enriches their experience and brings a new strength and diversity to their scientific world.

Responses from the teachers show that implementing a variety of instructional strategies to cater for learner differences increases learner success, motivated learners and met all learner needs. The participants expressed concern regarding the challenges they faced when implementing learning style-based instructional strategies. The teachers perceived that external factors such as limitation of resources, planning time, staff development and attitudes impact strongest on the teachers' intent to implement a diversity of instructional strategies.

The teachers express concerns about lack of adequate planning and non-utilisation of instructional time influence their efficacy. The teachers further opined that incorporating a variety of instructions adds unto their busy schedules. The time required for preparation and delivery was a commonly cited impediment to implementing learning style-based instructions.

During the classroom observation, it was found that the nature of instruction commonly practiced in the science classroom was aligned to the learners' learning style preferences. Billie's practices of matching teaching style to learners' learning styles were low with a high score of 104 as the low scores were indicative of matched instructions to learners' learning styles. In all the five facets of each section, Billie scored the highest. Billie practiced teacher centred instructional methodology and the work of the teacher was to overwhelm learners with information.

The four teachers sampled for the experimental study matched instructions to learners' learning style preferences in the teaching/learning process. The teachers encourage group activities and monitored the group hence the group discussions were often focused and based on practical investigations.

CHAPTER EIGHT
DISCUSSION: EXPLORING THE INTERACTIONS AMONG THE FOUR INVESTIGATED VARIABLES

8.0 Introduction.

The study reviewed literature and investigated the generic theories on the concepts of learning styles which helped the researcher to design learning style tool appropriate to be employed in the science classroom to identify the common learning styles among the sampled learners. In addition, the study aimed to do an empirical investigation to determine the role played by culture, as well as gender of the learners in influencing these learning styles, to develop learning style-based instructional strategies and to test if they impact learner academic achievement in physical sciences.

Nonetheless, the following sub-questions which emanated from the main research question guided the study:

- With regards to the learning style index, what are the prevailing learning styles that are common among these learners?
- How can knowledge of the cultural attributes of learning be used to determine the most likely learning style favoured by learners?
- What relationships (if any) exist between the teaching styles currently used by the teachers sampled for the study and the most common learning styles of their learners
- What impact, if any, does a learning style-based instruction have on learner academic achievement in physical sciences?
- To what extent and in what ways do the learning style-based instructions impact on learners' and teachers' experiences towards teaching and learning?

Answers to the above research questions were presented in the preceding chapters. This chapter critically discusses the findings from the study and linking them to the appropriate literature. The discussion is presented around the specific research questions.

8.1 Learning style profiles of the entire sample

The study's first research question was stated: "With regards to the learning style index, what are the prevailing learning styles that are common among these learners?"(See section 1.3).

In the quantitative study, it was found that the sampled learners have different learning style preferences. These learning style profiles with reference to index of learning style questionnaires were active or reflective, sensing or intuitive, visual or verbal, and sequential or global. The percentages though, varied between the preferences. Overall, 149 of the learners representing 60.8% were classified as active learners, forming the majority of this category while 96 respondents, representing 39.2% were considered as reflective learners. One hundred and ninety-six (80%) of the respondents were classified as being sensing learners, while 49 (20%) were intuitive learners, with the sensory learning style category forming the majority of this dimension. Considering the input learning style dimension, 166 (67.8%) were identified as having visual learning style, which form the majority of this dimension, while 79 (32.2%) of the learners were identified as verbal learners. For the understanding of learning style category, a majority of the learners, 169 (69.0%), were identified as sequential learners while 76 (31.0%) of the learners had global learning styles. This finding is conforming to findings informed in previous studies that reported on the existence of learning styles among students at all levels of the educational ladder over the past decades and a few recent studies (see Akinbobola, 2015; Bosman, 2018; Broberg et al., 2008; Felder & Silverman, 1988; Harvey et al., 2010; James-Gordon & Bal, 2001; Palou, 2006; Tyndall, 2017).

The findings showed that learners from the different schools revealed distinct learning style preferences. For example, the *active, sensing, visual and sequential* learning style profiles were found to be in the majority among all the learners from the sampled schools. The *active, sensing, visual and sequential* learning style profiles also emanated as the majority learning style profiles during the interviews with the sampled learners, which concurred with the findings from the quantitative study. More details about the learners' use of their learning style profiles were explored in the quantitative study. Those learners who were interviewed indicated that they liked dealing with proofs, raw data and investigations, and being hands-on with activities during the teaching/learning process. They also liked to indulge in cognitive processes when solving problems and like to work with solid materials after they have grasped the content. This finding corroborates those of Gonzales, Glaser, Howland, Clark,

Hutchins, Macauley and Ward (2017) who determines the learning style profiles (using FSLSQ questionnaire) among nursing students to be *active, sensing, visual and sequential*. This finding corroborated with the findings of Tyndall (2015). In his study of the alignment of teaching styles with students' learning styles, he revealed that there were more participants who were active learners, sensing, visual, and sequential learners. Tyndall's study further found that, on the sensing/intuitive dimension, 110 (53.7%) of respondents were well balanced on the sensing/intuitive dimension. However, the result indicates that 68 (39.5%) of students have moderate preferences for the sensing profile. This finding is also in tune with the findings of Akinbobola (2015) that there were more sensing learners in Nigerian secondary school physics classrooms than other types of learning styles. However, only 11 (33.3%) of the total respondents were considered to have a moderate preference for the intuitive learning style.

Findings of the study revealed a reasonable percentage of the sampled learners having preferences for different learning styles in the entire Felder-Silverman learning style dimension stated above. In this regard, this study confirms existing knowledge (e.g. Genovese, 2004; Gonzales et al., 2017; Jahanbakhsh, 2012; Lu & Yang, 2018; Mohamad, Heong, Hanafi, & Yusof, 2013). In the literature reviewed, Harvey et al. (2010) and Palou (2006) reported that the overall learning style profile patterns of STEM students were found to be active, sensory, visual and sequential. This is in agreement to the outcomes of Garner-O'Neale and Brooks (2013) study who found that majority of chemistry students at the University of the West Indies Cave Hill Campus had a preference for active, sensing, visual and sequential learning styles. This finding is also parallel to another study by D'cruz, Rajaratnam and Chandrasekhar (2013) who also reported that the students were fairly well-balanced in the sensing/intuitive learning style dimension. Felder and Silverman (1988) assert that individuals have preferences to receive and process information in a learning environment. This is not surprising since it is generally expected that physical science learners would be active rather than reflective since they are usually involved with experimentation, hypothesising and testing their hypothesis rather than processing introspectively.

It was found in the study that learners have distinct learning styles, which acknowledges the view that learning styles recognise the uniqueness of learners in the learning process. Learning styles are neither right nor wrong, and no particular learning style is deemed

superior to the other, as pointed out by Van Rensburg (2009). Recognising learning styles and incorporating it in the learning process is essential.

When the results of the qualitative study were further interrogated, it became evident that learners used not only their preferential learning style, but many other learning styles and learning behaviours when learning electricity and magnetism. It is therefore important that learners should be given the chance to evaluate their individual learning styles and be motivated to develop these preferences. Teachers should also encourage their learners to utilise learning styles which they favoured to enhance their understanding. Encouragement of interaction and discussion has also been supported by Felder and Spurlin (2005). They contend that identifying and sharing the outcomes of learners' learning styles gives the learners a chance to recognise their own strengths and weaknesses and to work on improving their performances.

As a whole, the findings revealed that, learners in each particular school had their peculiar learning styles; there were evidence of certain learning styles common among learners in each school. For example, learners in different schools tended to reveal distinct learning styles (for example, learners from school A prefer a sensing learning style). This was reviewed when the learners completed the learning style questionnaire and supported by the interviews. The less frequently used learning styles are the intuitive and the global. Kolb (1984) points out that the usage of distinctive learning styles is most often the outcome of selection and enculturation processes in the learning environment.

In the literature reviewed, it was found that gender differences exist in learning styles (Choudhary, Dullo, & Tandon, 2011; Chuang, 2009; Lau & Yuen, 2010; Middleton, Ricks, Wright, & Grant, 2013; Wehrwein, Lujan, & DiCarlo, 2007). The study finds that most females prefer to be active, sensory, visual and sequential learners compared to males. Nevertheless, from a general viewpoint, irrespective of gender differences, a majority of the physical sciences learners prefer to perceive information in the forms of active, sensing, visual and sequential learning style categories.

This result means that there are differences among learners in terms of how information is received and processed in the learning situation. As evident in this study, the prevailing learning styles among the sampled physical sciences learners, according to the FSILSQ, were found to be active, sensing, visual and sequential.

8.2 Cultural influence of learning style preferences

In section 1.3, the following research question was stated: "How can knowledge of the cultural attributes of learning be used to determine the most likely learning style favoured by learners?"

This study found that most learners belong to high power-distance cultural backgrounds and are not likely to pursue knowledge enthusiastically through their individual experiences. It was also found that the learners accept information from the teacher without questioning the power of the teacher, and furthermore, not engaging in any form of argument with the teacher. Thus, the necessity for learners to gather material through actively during learning is low, while the necessity to organise and make meaning of the material provided by the teacher is high, leading to learners in high power-distance cultures having input (verbal/visual) learning style preferences. Class discussions tended to be more like explanations rather than discussions. Learners are dependent on their teachers in everything they teach. One common trend identified from learners' responses was that elders cannot be questioned and that elders should be accorded with respect. This finding corroborated with the findings of Leoisa and Suping (2014). In their study, it was revealed that learners were raised to observe authority and respect elders. They further indicated that, although respect for elders is worthy and should be encouraged, it may compromise the learners' schooling as they would be left with uncertainty which become problematic since constructivists believe that learners' inceptions of knowledge are derivative of phenomenology in which learners create distinct meaning of their experiences (Amineh & Asl, 2015). The learners' interpretation of tasks in examination and quizzes, as well as the analysing of tasks and experiences would yield knowledge that may have little correspondence to external reality. According to Brown, Ash, Rutherford, Nakagawa, Gordon, & Campione, (1995), these constructions of knowledge are clarified through a process of social intervention.

Furthermore, the study found that most learners grew up in collective cultures and tend to learn to reason instinctively of themselves as part of a group. In collective communities, instinctual understanding of circumstances plays a vital role and unquestioning loyalty is anticipated and presumed. The collectivist culture is associated with processing learning style (active/reflective). Responses from the learners indicated that they liked working in groups and handling materials together as a group. When they were probed further, learners also

confirmed that they learn well when they are given the opportunity to contemplate and reason on the material presented to them (see section 6.3). This was established in the qualitative study. It was also revealed during the interviews that the active learning style emerged as the major learning style in the quantitative study. This means that most learners in this group liked being involved in the learning process and liked working in groups. One reason for this could be because physical science is a hands-on subject; the learners design, draw up procedure to carry out the activity and make assumptions which requires that they work as a group and work responsibly to be independent as well.

This study further found that most learners belonged to the high uncertainty avoidance cultures. According to Jaju, Kwak and Zinkhan (2002), high uncertainty avoidance is related to students being contented with the controlled learning environments and apprehensive with concrete materials. Such cultures place value on the material and information provided by the teacher and deems it as the paramount justification to the problem.

It was also revealed in the study that learners with sensing/intuitive learning style have a liking of dealing with facts, raw data and experimentation to gather information about a phenomenon, are also impatient and often get bored when presented with details. This finding was also confirmed during the direct classroom observation, where learners were seen to be hands-on with their activities as they gathered data for experimentation.

This study found that long-term orientation cultures were positively associated with understating (sequential/global) learning style preferences, since learners were able to follow a linear reasoning process when solving problems. Thus, people in such cultures are habituated to cherish their past practices and to think about them as they work with an explicit material once they have comprehended it superficially. According to Hofstede (1986), education in societies with long-term orientation is seen as a gathering of material that is necessary to attain the skills necessary for long-term goals. According to Hofstede (1986) learners thus take instinctive leaps with the material, may struggle to explain how they obtained a specific outcome, and therefore may need an integral idea.

This finding means that culture and learning styles are interconnected and that people experiences in life and their societal beliefs and values do not only affect their expectations in life, but also their processes of learning. Thus, learners who share similar cultural features have collective ways of learning and that, in order to address these diverse learning styles,

teachers should implement a variety of teaching styles to compliment learners learning styles to improve learners retention and success in physical sciences.

Findings from the teachers' interviews indicated that, within a culture, as people come together and interact, their ways of thinking, beliefs and their sense of right and wrong are transmitted to each other and to the following generations. This means that since learners' cultural backgrounds influence their learning style preferences, teachers need to use culturally compatible content and instructional methods that replicate the distinctive social, logical and contextual views of the learners to promote cultural infusion in the classroom teaching/learning processes. This will improve learners' achievement in the subject.

8.3 The relationship between teachers' teaching styles and learners' learning styles

In section 1.3, the following question was stated: "What relationship (if any) exists between the teaching styles currently used by teachers in the four Mthatha schools and the most common learning style of their learners as determined by the index of learning styles?"

This study revealed that the four teachers sampled for the experimental study consistently adapted their teaching style to the respondents' common learning styles and provided them with feedback. A significant feature of the study was the suitability and consistency of the adaption of instructional methodology with participants' common learning styles. This, according to the respondents, made learning easier and improved their participation in the classroom. The respondents also reported during the interviews that the adaption of instructional methodology with participants' common learning styles led to an increase in learner science classroom participation, made learning less challenging and improved learner academic performance in physical sciences. Another key finding was that the teachers consistently aligned instructions to learners' learning styles which made learning easier for their learners and further engaged learners in the learning process. Data from each classroom observation corroborated this finding. The classroom observations showed that participants' learning styles were matched with appropriate instructional methods which improved learner participation in the classroom activities and engagements. This finding corroborated with the findings from the literature (Coldren & Hively, 2009; Felder & Spurlin, 2005; Griggs et al., 2009; Kamuche, 2005) that suggests that learners' academic performance improves when learners' learning styles are considered in the teaching/learning process.

Findings revealed in the current study also corroborate existing findings in the literature. Specifically, Wilson (2012) advocated that curriculum development and instructional methodology should be guided by students' learning styles and strengths. Students' achievements in institutions of higher learning are reliant on the congruence of learning styles and teaching styles (Hall & Moseley, 2005). Fritz (2002) and Williamson and Watson (2007) concur with this finding and argue that matching learning and teaching styles would make teaching more effective. Although matching teaching styles to learners' learning styles is extremely challenging, Felder and Brent (2005) suggest that teachers need to develop a teaching approach that caters for the learning style difference among learners in the science classroom.

This study further revealed that learners possess learning styles which they seldom use. A deliberate mismatch should therefore be encouraged so students are motivated to develop their occasionally used learning styles. Williamson and Watson (2007) suggest that intentional mismatches can assist both students and teachers to adjust to different learning environments.

In the qualitative study, it was found that the teachers delivered the subject content in ways intended to garb the learning styles identified among the learners, and that there was consistency and generally good performances indicated in the CCSSE scores of the observed teachers. This finding is parallel to the findings informed by the literature (Felder & Brent, 2005; Litzinger et al., 2007) which state that alignment of teaching styles with learning styles permits the teacher to use a teaching approach, which caters for the differences learners bring to the classroom.

This result means that teachers need to understand the learners' learning styles and consider a variety of teaching approaches for each learning experience. Whatever teachers discern about learning styles in general, and what they know about the styles of their learners, in particular, is fundamental to their ability to adapt instructional methods to address those learning style differences. Thus, if teachers honed their teaching according to learners learning style preferences, then learners would be more able to build on their existing strengths and explore other learning strategies that would best suit their needs.

8.4 Impact of learning style-based instruction on academic achievement

In section 1.3 the following research question was stated: "What impact, if any, does a learning style-based instruction have on learner academic achievement in physical sciences?"

The results of the quantitative phase of the current study showed that there is a statistically significant positive correlation between the learners' academic achievements in electricity and magnetism and learning style-based instructions (see section 5.1.3). The findings indicate a substantial variance amid the scores of pre-tests and post-tests. The scores of post-tests and the learners' success showed that learning style-based instructions impacted positively on learner success. The findings from this study concurred with the work of other scholars documented. In the literature reviewed, it was found that the matching of teaching styles with students' learning styles is needed for student performance to be improved at all levels of the educational ladder (see section 2.5) and hence, Bernardes and Hanna (2009), and Mangino and Griggs (2007) advocate for the matching of learning styles with teaching styles to improve students' academic achievement. This result corroborated with the findings reported in the literature which stated that congruence between teaching and learning styles is needed because learners are underperforming in schools due to the incongruity of teaching and learning styles (Lopus & Hoff, 2009).

The qualitative phase of this study further revealed that learning style-based instructions make science lessons interesting and understandable to the learners (see section 7.3). All learners interviewed indicated that they developed their own ideas from the teachers' instructions that required of them to reflect on their work and that this has subsequently improved their performance in the subject. A common factor which was emphasised through most of the learners' responses was that they developed a strong liking for hands-on activities which enhanced their retention and consequently improved their performances.

This finding is corroborate with the findings from the literature (Brahmakasikara, 2013; Damrongpanit & Reungtragul, 2013; Felder & Silverman, 1988; Ku & Shen, 2009; Tsai, 2013) that indicates that teaching strategies should be adjusted to improve students' chances for succeeding in schools. Pass et al. (2012) examined research results and found that the matching of instructors' teaching methods with students' preferred methods for learning directly influenced student performance. Another study conducted by Gokalp (2013) evaluated the learning styles of students and investigated the effect of their success. 140

students were sampled for the study from the Education Faculty, among whom 68 were art and 72 pre-school students-teachers. The study found that differences existed between the results of the first and final applications of the sub-tests on learning styles and academic success.

This finding means that learning style-based instructions were influential in learner academic achievement. This implies that the concepts taught through learners learning styles offered learners an opportunity to learn from different instructional materials. Therefore, instructional materials in the teaching learning process through teaching methods has to be designed mainly based on the nature of the science concepts and then to accommodate different learning style preferences, which could subsequently lead to improvement in the learners academic achievement.

8.5 Learners' and teachers' experiences with the learning style-based instructions

Research question 5: "To what extent and in what ways do the learning style-based instructions impact on learners' and teachers' experiences towards teaching and learning?"

The literature reviewed show that the quality of teaching was considerably enhanced if teachers altered their teaching styles to cater for the diverse learners in their classrooms as suggested by Kamboj and Singh (2015). Kamboj and Singh (2015) further indicated that learning style-based instructions create learner-centred instructions, and make the class to be independent and less teacher-dominant, but stresses on students' active participation in the lesson. In this way, learner competence is improved.

The current qualitative study found that learners indicated overwhelmingly that learning style-based instructions were exciting, engaging and gave learners an understanding of the concepts taught. A common factor which was emphasised through most of the learners' responses was that they developed a strong liking for hands-on activities. They emphasised that hands-on activities engaged them in the teaching/learning process. Many learners indicated that they developed their own ideas from the teachers' instructions that required of them to reflect on their work. This finding corroborated the findings of Packer and Bain (1978) who indicate that it was easier for learners to appreciate the learning process when teachers' teaching styles were aligned with learning styles.

A common trend which was emphasised through most of the learners' answers was that they adored teachers who elaborated on the science concepts by utilising different instructional strategies, specifically, the use of resources such as charts, figures, and illustrations and that detailed explanations and good examples ensured that they understood all the concepts their teachers taught them. There were comments on peer teaching, and group work as a style-based instructional strategy when studying physical sciences. Some learners indicated that they liked science teachers who give tasks on work done in class as a group and assigned responsibilities to group members while others mentioned active learning. Many learners indicated that they took the edge to engage in the lesson and developed a profound grasp of the subject. This finding concurred with the findings of the study by Packer and Bain (1978) who pronounced that it was easier for students to appreciate the learning process when teachers' teaching styles were in alignment with their learning styles to improve student attitudes, teamwork, citizenship, ethical behaviour and performance.

When the results of the qualitative study were further interrogated, it became evident that learners preferred teaching styles that facilitated practical activities. Proponents of the learning styles framework (e.g. Aliweh, 2011; Felder & Silverman, 1988; Kyprianidou et al., 2012; Tulbure, 2012) believe that congruence between teaching and learning styles is an effective pedagogical approach designed by best practice.

The qualitative study further found that learning style-based instructions impact on learners' interest, motivation and achievement in physical sciences. Most learners believed that the implementation of the learning style-based instructional approaches stimulated their interest and curiosity in the subject as learning becomes more understandable. This finding corroborated with the findings of the study by Felder and Henriques (1995) and Reid (1995). Alnujaidi (2019) found that aligning instructions to learning styles give students an opportunity to learn, allow them to become conscious of their strengths and weaknesses, and ultimately influence their learning, assertiveness, conduct and enthusiasm.

Another group of respondents limited the use of the learning style-based instructional strategies to motivation. This group believed that using these strategies in the science classroom has motivated them to improve their learning in the subject. Forty per cent of the respondents limited the influence of -based instructions on accomplishment. This group of learners believed that their academic performance in the subject has improved since the

introduction of the learning style-based instructions. This is consistent with the findings from the literature. More specially, Cassidy (2004) found that students' performance is enhanced when teaching methods are congruence with learning styles. This finding was further corroborated by the findings of Brown, Terry and Kelsey (2013) who stated that, when students' learning styles correspond with appropriate teaching styles, their enthusiasm, and achievements are enhanced.

With reference to learners' responses on their personal perception of the impact of learning style-based instructional strategies on their ability in physical science, most of the learners contend that they now find the subject enjoyable and interesting and that they are capable of doing more and improving their performance in the subject. There were comments on the satisfaction that the subject provides for learners. Many learners indicated that the subject has given them the satisfaction that physical science is like other subjects and it is not as difficult as they thought it was.

There were comments made by the learners about their change in attitude towards the subject. Some learners stated that their attitude towards physical science as a challenging subject has changed. The learning style-based instructional strategies have helped them to see the subject as one that they enjoy studying every day as it is easier because of the strategies their teacher used. They mentioned that they now get the chance to voice their feelings as they take part in the lessons. In addition, they mentioned that they now realise that physical science is as bad as they thought it was. The learning style-based instructions have made learners realise that they do not hate the subject but they can study and practice it to achieve higher marks.

When respondents were asked to describe the nature of practical activities which influence their achievements in the physical sciences, they gave a myriad of responses. The respondents contend that they learn more when taught through practical activities. While for many learners there was congruency between the views they expressed in the interview and their responses to related items, some learners gave contradictory responses. Two learners thought that practical activities are more related to real life and, as such, they make science activities relevant. However, many learners share the view that practical activities help them to grasp the concepts and improve their marks. Practical activities broaden their understanding about the topics in electricity and magnetism and also enhance their knowledge of science concepts.

When asked about the instructional material that emphasises conceptual and theoretical

explanations, some learners responded by saying that they prefer learning concepts and theories to practical activities because instructional materials give adequate explanations. This finding substantiates those of Dubetz et al. (2008), Honigsfeld and Schiering (2004), and Landrum and McDuffie (2010) who argue that multiple instructional strategies are important to reach individual students with diverse learning styles.

As noted from learners' responses, majority of learners claimed that visual representations of instructional materials allowed them to perform better. Visual representations of instructional materials refer to the instruction materials characterised by diagrams, models and mathematical and symbolic representations. All the learners noted that they remember information shown to them in a form of a diagram. There were comments on diagrammatic representations which induce learners' understanding and stimulate them to focus on the lesson.

Findings from the teachers' interviews indicated that implementing learning style-based instructions led to learners' having good learning experiences and improving their achievements in physical sciences. There was a common trend in the teachers' responses to involve learners with diverse learning styles in the science classrooms. Responses from the teachers indicated that intensifying the use of different teaching methods is not an immediate shift towards differentiated instruction but rather a gradual process, trying new methods step-by-step possibly for just a class period.

When asked about teacher s' views regarding the challenges of implementing learning style-based instructions in their science classrooms, the teachers expressed concern about the lack of essential teaching resources, preparation time, materials, and funding. One teacher was concerned about learners' behavioural problems and their attitudes towards the implementation of learning style-based instructions. The challenge of handling large classes with many different learning styles poses a big problem for many science teachers. The teachers perceived that external factors, such as a limitation of resources, planning time, staff development and attitudes, influenced the implementation of diversity of instructional strategies.

This finding means that for a diverse group of learners, science teachers should differentiate and diversify their own teaching styles, although, it is neither likely nor desirable to modify instructions to suit individual learning styles of each learner, should teachers diversify

teaching methods to accommodate different learning styles during a science lesson. Thus, the different forms of instructional materials could be implemented in the science classroom to accommodate learners with different learning styles. Thus, instructional designers should use different formats of instructional materials in the ways that can benefit the majority of science learners.

8.6 Chapter summary

The chapter discussed the main ideas of this study in the light of the literature on the subject. The study finds that the sampled learners have different learning style preferences that were active or reflective, sensing or intuitive, visual or verbal, and sequential or global. This finding also corroborated with other studies reported over the past decades and few recent studies (see Akinbobola, 2015; Bosman, 2018; Broberg et al., 2008; Felder & Silverman, 1988; Harvey et al., 2010; James-Gordon & Bal, 2001; Palou, 2006; Tyndall, 2017).

When the results of the qualitative study were further interrogated, it became evident that learners used not only their preferential learning style, but many other learning styles and learning behaviours when learning electricity and magnetism. It is therefore important that learners should be given the chance to evaluate their own learning styles and be motivated to develop these learning preferences. Teachers should also encourage their learners to utilise their favoured learning styles for a productive knowledge acquisition. Teaching and learning should thus assist the learners in recognising and evaluating their distinct learning styles.

Encouragement of interaction and discussion has also been supported by Felder and Spurlin (2005). They contend that identifying and sharing the outcomes of learners' learning styles gives the learners a chance to recognise their strengths and weaknesses, and to work on improving their performances.

This study found that most learners belong to high power-distance cultural backgrounds and are not likely to seek out information enthusiastically through their own experiences. It was also found that the learners accept information from the teacher without questioning the power of the teacher, and furthermore not engaging in any form of argument with the teacher. Findings from the teachers' interview indicated that, within a culture, as people come together and interact, their ways of thinking and values are passed on to each other and to the generations to come. These teachers highlighted the values and behaviours within a society

and indicated that the values determine people's sense of right and wrong and these values are instilled in children over generations.

In conclusion, most cases it is not likely or appropriate to modify instructions to the learning styles of each learner. What is necessary, though, is that the teacher's diverse teaching styles provide an opportunity to for the learners with different learning styles during the experiences of a science lesson

CHAPTER NINE
CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

9.0 Introduction

The study explored the interactions between learners' learning styles, learners' cultural backgrounds and teachers' learning style-based instructional strategies in the learning and teaching of electricity and magnetism. The study also sought to investigate the sampled school teachers' instructional practices and how they affect learners' achievement in electricity and magnetism.

The evidence gathered suggests that these interactions between the investigated variables are complex and are influenced by other factors in the school setting that comprise: the nature of the curriculum, pressure to cover content, examinations, assessment demands, motivation, materials, learning orientation and the nature of instruction. In this concluding chapter, the major findings, conclusions, implications and recommendations of the study are summarised and the limitations of the study are given.

The sub-questions (see section 1.3) which emanated from the main research question were:

(1) With regards to the learning style index, what are the prevailing learning styles that are common among these learners?

(2) How can knowledge of the cultural attributes of learning be used to determine the most likely learning style favoured by learners?

(3) What relationships (if any) exist between the teaching styles currently used by teachers in the five Mthatha schools and the most common learning style of their learners?

(4) What impact, if any, does a learning style-based instruction have on learner academic achievement in physical sciences?

(5) To what extent and in what ways do the learning style-based instructions impact on learner's and teachers' experiences towards teaching and learning?

The way in which a group of learners experienced learning style-based instructional strategies

were investigated qualitatively and the findings were integrated into the results of the quantitative findings.

To answer these research questions, this study was conducted in five public high schools around Mthatha in the Eastern Cape Province, South Africa. Using a mixed methods design, the data were gathered using structured questionnaires, semi-structured interviews and observation schedules which were completed by 245 learners and 5 teachers. The conclusions that can be drawn from this research are discussed as follows.

9.1 Conclusions

The key findings which emerged are summarised under the headings of the five main research questions for the study.

9.1.1 Research questions 1: With regards to the learning style index, what are the prevailing learning styles that are common among these learners?

Analysis of the results presented in section 5.1.2.3 revealed the learning style preferences of learners in all the five schools sampled for the study, thus answering research question 1. The study showed that learners had individual and different learning style profiles and that certain learning styles were predominant in the different schools. The study found that there were more active learners among the respondents than reflective learners, more sensing learners among the respondents than intuitive learners, more visual learners among the respondents than verbal learners and more sequential learners among the respondents than global learners. Learners have a preference for a particular kind of learning style and the majority of them have dominance in one or more styles of learning. Within each learning style dimension, the study showed that the sampled learners have preferences for the sensing, active, visual and sequential learning style profiles. Hence, the researcher can conclude that the majority of the respondents possessed multiple learning styles as described by the Felder-Silverman learning style model.

When the FSILSQ was analysed, it was found that a majority of the females have dominant preferences for the active, sensory, sequential and visual learning styles. Nonetheless, irrespective of the gender differences, a majority of the physical sciences learners prefer to receive information in the forms of active, sensing, sequential and visual learning style

dimensions.

Further analysis of the FSILSQ shows that a majority of the respondents were well balanced on the active/reflective categories. Very few of the respondents have a moderate preference for either the active or reflective learning styles. On the sensing/intuitive dimension, results show that a majority of the respondents were well balanced on this dimension while a few of them had moderate preference for the sensing learning style dimension. This indicates that learners were cautious with facts, able to solve problems using standard procedures and incline to be more hands-on as affirmed in a study by Felder and Henriques (1995). This result correlates with the findings of Akinbobola (2015) that there were more sensing learners in Nigerian secondary school physics classes than other types of learning styles. However, only few of the total respondents were considered to possess a moderate preference for the intuitive learning preference.

Findings regarding the visual and verbal dimensions indicate that a majority of the respondents have preferences for the visual dimension in a moderate form and a few have a strong preference for visual learning. However, 15 or 7.3% of the total respondents have a moderate preference for verbal learning with a small number of three or 1.4% having a strong preference for verbal learning.

On the sequential/global dimension, a majority of the respondents, 142 or 69.3%, have a well-balanced preference for both dimensions, with 44 or 21.5% having a moderate preference for sequential learning, with a small number of five or 2.4% of the total respondents with a strong preference for sequential learning. Twelve or 5.9% of total respondents have a moderate preference for global learning.

9.1.2 Research question 2: How can knowledge of the cultural attributes of learning be used to determine the most likely learning style favoured by learners?

The results from RQ2 were presented in section 6.2 for both learners and teachers regarding how cultural backgrounds of learners translate into learning style preferences. This study found that most learners belong to high power-distance cultural backgrounds and are not likely to pursue knowledge keenly through their individual experiences. It was also found that the learners accept information from the teacher without questioning the power of the teacher and furthermore do not engage in any form of argument with the teacher. Therefore, the

necessity for learners to collect material through active involvement in the lesson is low, whereas the necessity to organise and make sense of the material being provided by the teacher is high. This leads to learners in high power-distance cultures having a preference for input (verbal/visual) learning style preferences. This may influence learners' performance in the subject since there is not much interaction that occurs between the learners and the educators.

Finding from the study further show that most learners grew up in collective cultures and tend to think intuitively of themselves as part of a group. In collective communities, intuitive understanding of a situation and unquestioning loyalty is expected and assumed. The collectivist culture is associated with a preference for an active/reflective (processing) learning style. Learner responses indicated that they liked working in groups and handling materials together as a group. When they were probed further, learners also confirmed that they also learn well when they are given the opportunity to reason and reproduce on the material presented to them (see section 6.3). This was confirmed in the qualitative study where it was revealed in the interview responses that the active learning style appeared as the major learning style in the quantitative study.

This study further found that most learners belonged to high uncertainty avoidance cultures. Uncertainty avoidance cultures hold in high esteem the information conveyed by the teacher and regard it as the best description of the problem. It was established from the interviews responses that sensing/intuitive learners liked to deal with facts, raw data and experimentation to gather information about a phenomenon and are also impatient with details and often get bored when presented with details. This was confirmed during the classroom observation, where learners were seen to be hands-on with their activities as they gathered data for experimentation.

This study found that long-term orientation cultures were positively associated with understating (sequential/global) learning style preferences, since learners were able to follow a linear reasoning process when solving problems. Therefore, people in these societies are accustomed to value historical knowledge and to reproduce them as they work with explicit information once they have grasped it comprehensively. Hence, educating people in such societies is seen as training them to acquire skills needed for the long-term goal.

Findings from the literature and from the learners' responses clearly indicate that culture and

learning styles are connected. Evidence from literature and from learners' responses show that individual early life experiences and values of their culture do not only affect their expectations in life, but also affect their ways of learning. Therefore, there is evidence that learners who share similar cultural characteristics have collective ways of learning.

Findings from the teachers' responses affirm the belief that teachers' teach the way they themselves prefer to learn. The teachers highlighted that their cultural values inevitably mould their views and influence their teaching styles. This result corroborates with the study by Palou (2006) who posits that the way a teacher prefers to use his/her cognitive abilities influences his/her preference for certain situations which impact upon his/her personal style of organising and using teaching methods. Palou (2006) emphasised that the teacher's teaching style emphasises his/her own learning and thinking styles and his/her way of measuring the performances, which influence the students in the classroom.

The study further found that when teaching strategies are adjusted to cater for the learners' cultural backgrounds, learners' interest in and motivation for the topic increases. According to Prowse and Goddard (2010), educational practices need to be clarified by incorporating aspect of culture to improve the teaching and learning of science.

This study further found that the idea of involving cultural activities in teaching, using case studies applicable to learners' culture in the science classrooms and approaching the teaching/learning situation in the science classrooms by providing hands-on experiences for the learners enhance learner understanding in the subject.

Doing scientific research which involves investigations related to the learners' cultural characteristics was found to augment learners' learning in the science classroom. Two teachers made references to instruction which takes cognisance of learners' learning style preferences in the teaching/learning process. The teachers highlighted that "if learners learn more about their culture at school and acknowledge the differences among themselves, then they will be confident about themselves and what they can achieve. Therefore, encouragement is vital as learners do not see themselves as capable. The finding is in line with the findings of the study by Richards, Brown and Forde (2004). They indicated in their study that fostering high expectations for the achievement of all students requires supporting learners in a culturally-based context to assist them to nurture their strengths to enhance their performance in schools.

9.1.3 Research question 3: What relationships (if any) exists between the teaching styles currently used by teachers in the five Mthatha schools and the most common learning style of their learners?

The findings from RQ 3 were presented in section 7.8, which indicate the appropriateness and regularity of the adaption of teaching styles to learners' learning styles. This, according to the respondents, made learning easier and improved their participation in the classroom. The learners further specified that the alignment of learning style-based teachings to their learning styles made learning less challenging and improved their academic performance in physical sciences. This finding was also confirmed by the teachers during the interviews. They consistently aligned instructions to learners' learning styles which made learning easier for their learners, further engaged learners in the teaching and learning process and enhanced learner performance in the class tests. The data collected from each observation corroborated that participant learning styles were matched to appropriate instructional methods which improved learner participation in the classroom activities and engagements. Also consistent with prior research findings (Abidin et al., 2011; Allers, 2010; Coldren & Hively, 2009; Felder & Spurlin, 2005; Griggs et al., 2009; Kamuche, 2005) is the result that learners' academic performance improves when learners' learning styles are considered in the course of teaching and learning. Overall, learners' achievement in school is shown as dependent on the alignment of learning styles and teaching styles.

9.1.4 Research question 4: What impact, if any, does a learning style-based instruction have on learner academic achievement in physical sciences?

The results from RQ 4 were presented in section 5.1. The study findings show a correlation between the learners' academic achievements in electricity and magnetism and learning style-based instructions (see section 5.1.3). The findings indicate a significant variance of the pre-tests and post-tests on learner achievements, as well as the mean scores of on achievements between the experimental group where learning style-based instructions were implemented and the control group where a traditional teaching strategy was implemented. The significant difference in the mean scores of post-test and the learner achievement show that the learning style-based instructions impacted positively on learner success. Findings from this study are in line with the work of other scholars. In the literature reviewed, it was affirmed that, when learning style preferences of learners are considered during teaching, the academic achievements of learners are greatly improved (Dunn, 2000; Graf, Liu, & Kinshuk, 2010) (see

section 2.2.2). It is also evident from the analysis of the learning style models presented in section 2.3 (Dunn & Dunn, 1992; Felder & Silverman; 1988; Gregorc, 1979; Kolb, 1984;) that using learning style to apprise the selection of learning activities will allow learners to improve on their achievements in the subject (Hawk & Shah, 2007).

9.1.5 Research question 5: To what extent and in what ways do the learning style-based instructions impact on learners' and teachers' experiences towards teaching and learning?

The study findings presented in section 7.2 reveal that learning style-based instructions allowed the learners to actively participate in the lesson, become more independent and show more apprehension for their desires for instruction. Along these lines, learner competence is improved. Findings from learners' responses further indicated overwhelmingly that learning style-based instructions were regarded as exciting and engaging, and that learners understood the concepts taught. A commonality that was found in most of the learners' responses was that they developed a strong liking for hands-on activities because they engaged them in the teaching/learning process. Many learners indicated that they developed their own ideas from the teachers' instructions that required them to reflect on their work. Also consistent with prior research findings (Packer & Bain, 1978) is the result that participants indicated it was easier for learners to appreciate the learning process when teachers' teaching styles were aligned with their different learning styles.

In addition, this study established that learners liked the fact that their teachers elaborated on the science concepts by utilising different instructional strategies, for example, the use of figures, illustrations, demonstrations and comprehensive explanations with detailed patterns to make certain that learners grasp the science concepts. Many learners indicated that they took the initiative to engross in the lesson and by so doing; they developed to a great depth, a good understanding of the subject. This result once more parallels the findings from Alnujaidi (2019) study, which shows that, students appreciate the learning process when teachers' teaching styles were in alignment with their learning styles. This improved students' attitudes, teamwork, citizenship, ethical behaviour and performances.

Findings from Chapter Seven show that learning style-based instructions increase learner success, motivate learners, and meet all learner needs. However, the teachers expressed concern regarding lack of teaching learning materials and funding, as well as learners'

behavioural problems and attitudes towards the implementation of learning style-based instructions. Teaching according diverse learning styles was found to poses a challenge for many teachers. The teachers also perceived that external factors, such as limited resources, planning time, staff development, and attitudes were the strongest influences of the implementation of teaching methodologies that are aligned to the diverse learners in the science classroom.

The teacher's teaching styles provided diversity of instructions to suit the needs of learning style difference in the classroom which motivated the learners. While there is a plethora of variables that may influence learners' learning in the science classroom, the variables that were investigated were found to affect these relationships. Along these lines, this study adds to the conception-practice discourse, by employing mixed methods designs to understand the associations anticipated in the literature.

9.2 Theoretical findings

Five learning style models were analysed for the study and only one learning style instrument was adapted to the South African basic education context of the study. These instruments are: the Curry Onion (1983) Model of learning style, the Ellis (2001) learning styles, the Kolb learning style (1984), Gregorc (1979) learning style model and Felder-Silverman (1988) learning style model.

The Felder-Silverman's learning style theory was selected for this exploratory study because it met the criteria determined by the researcher, that it is applicable to science, it was available free of charge, it was self-reporting and self-scoring, easy to complete and could be scored manually. The sub-sections that follow present the theoretical findings of this study.

9.2.1 Conceptualisation of learning styles

Findings from the literature reviewed showed that there are variations in the definitions of learning styles, but the one that commands benchmarking significance is the quote by Keefe (1979), "Learning styles are characteristic cognitive, effective, and physiological behaviours that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment" (p. 4) (see section 2.1). Learning styles, according to Reid (2005), also overlap with other important aspects of learning, such as learning theories,

learning strategies, intellectual styles, thinking styles, multiple intelligences, cognitive styles, metacognition types and teaching styles (p. 56). Learning styles are often added to the concept of learning strategies. Hill (1976 cited by De Bello, 1989) defined the concept as being the way in which an individual pursuits for meaning. Hill (1976 cited by De Bello, 1989) believes that cultural determinants are of great value in the learning process. Informing learners about their learning styles and strategies does not only prepare them for learning, but also makes them more analytical about their ways of making meaning and the approaches they use to learn. According to Farajolahi and Nimvari (2014), knowledge of one's own learning style is essential in "learning to learn" as it enables students to take control of their learning whilst still allowing them to maximise their potential for learning (p. 159). Therefore, as suggested by Tuan (2011), learning styles can be regarded as "comfort zones" or the educational conditions under which students learn best (p. 287).

Although much of learning styles research (Lovelace, 2005; Pashler, et al., 2009) has been devoted to defining the concept and given evidence that differences exist in the ways learners receive and process information, the models overlap in many ways. For example, studies by Denig (2004) and Young (2002) investigated specific methodologies to identify, classify and assert schemes to learning styles and their relevance for education. Although extensive research supports the notion of individual differences, learning style scholars often describe the concept differently.

Furthermore, there are many definitions and descriptions on learning style conceptualisations and an extensive difference in scales of measurement of learning style inventories. However, the data gathered as evidence to substantiate the various conceptualisations of learning styles vary in terms of psychometric standards. Contending notions about learning have led to a propagation of terms and concepts, many of which are used conversely in learning styles research.

9.2.2 The link between learning styles and culture

The literature found that culture, according to Barmeyer (2004), is determined by socialisation through institutions, such as family, friends, school, universities and work (p. 586). These factors influence the development of learning styles and create a system of shared values, assumptions and knowledge. Consequently, culture can be associated with

learning style development. These views are shared by Joy and Kolb (2009) who state that many researchers have observed that cultural differences among students have a significant impact on the learning process (see section 2.4). Barmeyer (2004), using Kolb's LSI (see section 2.4.1) in his study found differences amongst French, German and Quebecois students and their learning styles. In connection with the CE (feeling) scores, the French and Quebecois students scored higher than the German students. In another research conducted by Heffernan, Morrison, Basu and Sweeney (2010), it was found that both Chinese and Australian students prefer active learning than reflective learning, with a greater percentage of Australian students being more active. Australian students were also more visual, more verbal and more sequential than their Chinese counterparts. According to Joy and Kolb (2009), culture as a way of life has an influence on the learning style preference that is parallel to specific demographic characteristics of students. Culture, therefore has a significant impact in determining students' preference for nonconcrete conceptualisation and concrete experience.

9.2.3 The link between learning styles and academic achievement

A number of studies (Bosman & Schulze, 2018; Elçi, Kiliç, & Alkan 2012; Peters, Jones, & Peters 2008) the academic success of students is greatly improved when learning styles are considered in the teaching learning process. In a research done on medical education students using Kolb's LSI (see section 2.4.1), it was found that accommodating learners were more positive towards problem-based questions and succeeded in their tasks, whereas assimilating learners were more positive towards theoretical questions and achieved in their theoretical tasks. In science and mathematics, both convergers and assimilators were more successful and demonstrated better academic performances (Kablan & Kaya, 2013). Kablan and Kaya (2013) also conclude that the impact of learning style on academic achievement is dependent on the instructional methods, subject area, and the assessment techniques being used.

9.2.4 The link between learning styles and teaching styles

Findings from the literature (Morrison, 2006; Noble, 2004) show that alignment of teaching and learning styles does not mean that teachers should implement learning activities that match each learning style preference, but reasonably present instructions in such a way that learners learning styles are considered in the process. Thus, when teachers are given appropriate material and resources, there is a possibility for enthusiastic acceptance of

teachers in employing variety of teaching methodologies to help students accomplish academic success (Honigsfeld & Schiering, 2004; Noble, 2004; Rosenfeld & Rosenfeld, 2008).

A study by Felder and Henriques (1995) on students' learning styles found that knowledge of students' learning preferences has a substantial effect on student achievement. Their study further found that learner performance increased as the mismatch between learning styles of learners and teaching styles of teachers was removed. Felder and Silverman (1988) and Felder and Dietz (2002) studied the impact of learning styles and teaching styles in engineering education. They found in their study that the awareness of learners' learning preferences contributed to learner success. Furthermore, a study by Felder and Brent (2005) on the influence of learning styles on students' academic success found that learners with learning styles that are congruent with the teacher's instructions improved in their performance. However, the study also found that students whose learning styles were incongruent with the teacher's teaching instructions underperformed.

Nevertheless, Felder and Brent (2005) were of the opinion that a teaching strategy that meets the needs of students' diverse learning styles in the class is appropriate to enhance learner achievement in science. Tyndall (2017), in determining the effects of adjusting instructions to bring into line to students' learning styles on their academic achievement established that students achieved success because of the congruence of teaching and learning styles.

9.2.5 The link between learning styles and gender

Several studies demonstrated that females and males learn differently (Keri, 2002) (see section 2.3). Research conducted by Bhatti and Bart (2013) using Kolb's LSI (see section 2.1.2), established differences in learning styles amongst male and female learners. Females tend to prefer to experience new information concretely, whereas males prefer to experience new information through abstract conceptualisation. In another study conducted by Aliakbari and Qasemi (2012) in Iran, the majority of the female students preferred an assimilating and diverging learning style. Only a few females had preferences for a converging or an accommodating learning style. Durmuşçelebi (2013) also found similar gender differences in relation to learning styles. In his study, females mostly have divergent, accommodator and assimilator learning styles.

Prajapati, Bartlett and Cubbidge (2011) investigated the learning style differences among males and females using the Felder and Silverman LS model (see section 2.4.6). Prajapati, et al did not find any gender difference on the sensing-intuitive dimension and the sequential-global dimension of the FSLSQ tool, though there was a substantial variance amongst males and females on the active-reflective dimension and the visual-verbal dimension. Females were more likely to have a reflective and visual learning style in comparison to males. However, Prajapati et al. (2011) noted some inconsistencies with findings from studies where it was found that female health science students were more likely to have a preference for verbal and active learning, whilst others found no gender differences.

9.3 Recommendations for teaching and learning

Based on the study findings, the subsequent recommendations are offered for application in the high school science teaching and learning:

- The learning style-based instructional materials developed for this study could be implemented in both junior secondary schools and senior secondary schools science classrooms across South Africa for effective teaching.

- High school science teachers should be motivated to reflect on their teaching style profiles as they implement learning style-based instructions.

- Science teachers should assist learners in understanding their responsibility in the course of teaching and learning. This makes certain that learners become cognisant of their learning style profiles.

- Science teachers should consider learners' learning style preferences, as well as their strengths and weakness as basis for their classroom instructions during lesson preparations.

- Science teachers should encourage their learners to use their non-dominant learning styles by varying their teaching strategies, and providing learner support materials during classroom instructions.

- Since the learning style assessment tool adapted for this study was written in English to facilitate language accessibility, the assessment tool could be translated into all the

eleven official languages in South Africa.

- The learning style-based instructional materials developed for this study could be amended so that it can suit all fields of study in the high school context.

9.4 Recommendations for future research

Some issues emerged from the study which could not be addressed in this study. For that reason, the study provides recommendations for further research:

- Further study could be conducted with a bigger sample to determine if comparable results could be achieved, thereby developing reliability coefficients.
- A longitudinal study could be carried out with the same learners when they are promoted to grade 12, to ascertain the stability of the learning style profiles.
- A longitudinal study could be carried out with learners in high schools from grade 8 to grade 12 to create awareness of learners' learning style differences.
- Further research could be conducted to examine the significance of matching teaching and learning styles to ascertain learner achievement in the subject.
- Research could be conducted to further explore whether learners' knowledge of their learning styles improves learning.
- Further research could be carried out to explore the cultural background influence on learning style and how this could be incorporated in the physical science classroom instructions.
- The study could be repeated in other schools, for example, in rural and sub-urban high schools, colleges or university environments.
- Further study could be engaged in to investigate the impact of second language as a medium of instruction on science learners learning style preferences.

9.5 Implications of the study

The problem discussed in the introductory section of the study is that physical science

learners frequently underperform academically. One possible reason for this underperformance of these learners was the incongruity between teaching and learning styles. Researchers widely agree that a lack of designing instructions which focused on learner needs and diversity could negatively impact the retention and engagement of students and their academic performance. Addressing deficiencies in learning style-driven teaching could alleviate those negative impacts, improve science education and result in better academic achievement for high school physical science learners.

This study was intended to address the absence of learning style-driven teaching approaches in high school science education. The study is in agreement with several previous studies that established the often unmet need for diversified teaching in high school physical sciences classrooms. This finding is not new but then again previous studies have concentrated on the whys and wherefores for the lack of differentiated teaching methodologies. The hindrances identified in this research are addressed in this study. They are all common problems in science education but are not insurmountable barriers to the use of varied teaching strategies. Subsequent studies could investigate the same research questions, with a larger sample, using both educators and students, or venturing outside the realm of science education and into other educational fields. Another possible approach could be a comparative study of student attitudes and performance preceding and following application of the remediation program proposed in this study.

9.6 Limitations of the study

As the study progresses, some limitations were stumble upon and acknowledged. Some of these limitations could form the basis for further research.

- The study was undertaken in a high school setting that provides a context for studying learning style-based instructional strategies and its impact on learner performance in the subject. This might be a limitation on the applicability of the research in other educational institutions. Since this is a doctoral study, it implies the research was limited to one researcher and thus could not obtain multiple researchers' perspectives (Wynn & Williams, 2012).

- Not all the existing learning style instruments were readily available to the researcher as they were prohibited by copyright and some of them needed to be purchased. This

study thus was restricted to the accessibility of learning style instruments.

- This study could only afford to use the learning styles tools and models that were freely available on the internet since some of the learning style instruments were too expensive.

- The finding from this study could not be generalised further than the sample group, since the study only employed a convenient sample from five schools within the O.R.Tambo Inland municipality of Umtata, Eastern Cape.

- Even though the medium of instruction was English in the schools that were sampled for the study, all the participants were Xhosa speakers and only used English as their second language. However, the researcher being a non-Xhosa was not able to provide detailed explanation when required in the learners' home language but could prompt the teachers to provide explanations, allowing the learners to speak in their language of choice. This could have had a bearing on the identification of their learning styles.

- This study employed a small sample size of five physical sciences teachers (n=5) and two hundred and forty five physical sciences learners (n=245). The different numbers of participants within each class (between 38 and 58 learners per class), as well as the small total sample size for teachers (n=5), makes statistical use for identifying trends problematic.

- For the reason that this study is empirical in essence, general patterns emerging were elicited through qualitative methods. Differences are therefore based on relative comparisons and, in few cases, only as a follow up to statistical significance where a relevant statistic was utilised.

9.7 Conclusion

The South African government has prioritise the effective teaching and learning in high school educational institutions across South Africa. Measures should therefore be taken to promote effective implementation of this policy through the utilisation of learning style-based instructions. The this study aimed at developing and implementing a learning style-based instructions that is appropriate for the South African high school context with the expectation of improving learner performances in physical sciences.

Awareness of learning styles and learning style-based instructional strategies provide a basis for effective teaching and learning. This includes knowing learners' strengths and weaknesses in learning, identifying their learning style preferences and knowing their cultural backgrounds which might influence their learning style preferences. Awareness through learning style assessment empowers students to recognise how they themselves learn and thus maximise their learning prospects. The FSLSQ employed in this study was able to assist the learners in reflecting on how they learnt and to ascertain their diverse learning styles. Similarly, the learning style-based instructional strategies implemented in the schools were able to assist the learners to improve upon their performances in physical sciences.

With the changes taking place in South African basic educational institutions, there has been a greater emphasis on learner academic achievement. Learners' strength and their weakness, the way they see themselves, their abilities and self-esteem need to be recognised and appreciated to encourage them to learn.

To this end, basic education institutions need to stress the role of learning style-based instructions in science teaching and learning. According to Lauria (2010), the most important aspects of integrating learning style-based instructions in the science classroom is to assist teachers to be more responsive to the distinctive characteristics of each learner in the science classroom. It is therefore hoped that teachers would shift from the traditional methods of instruction which render learners passive in the teaching-learning situation. Teachers need to engage in discourse with their learners to facilitate the teaching-learning process to enhance learners understanding.

It is anticipated that this study findings would enable students to recognise how they learn and to improve upon their learning and become self-regulating and self-determining learners. It is also hoped that this study findings would assist science teachers to appreciate their students' learning differences and develop approaches to support them in their studies. The study finding validates the existence of learning style preferences and teaching styles. The study also shed light on important mean to evaluate these processes.

The study findings presented here offer a positive affirming and non-constraining perspective on the potential uses of the learners' learning styles and learning style-based instructional materials. This study noted, without judgement, the learning style differences that were apparent amongst science learners from the different high schools. These preferences are an

indication that learners learn in different ways.

Based on the findings, the study also recommended ways to improve learners' learning and academic achievements. Thus the research makes a valuable contribution to new knowledge relating to teaching and learning in the South African science classroom context.

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APPENDICES

APPENDIX A1: Felder-Silverman Index of Learning Style Questionnaire (FSILSQ)

This questionnaire seeks to find out what your learning style preferences are. There is no right or wrong answer. Just indicate what you believe in or think**.**

Instructions

Enter your answers to every question on the FSILSQ scoring sheet. Please choose only one answer for each question. If both "a" and "b" seem to apply to you, choose the one that applies more frequently.

1. I understand something better after I

a) try it out.

b) think it through.

2. I would rather be considered

a) realistic.

b) innovative.

3. When I think about what I did yesterday, I am most likely to get

a) a picture.

b) words.

4. I tend to

a) understand details of a subject but may be fuzzy about its overall structure.

b) understand the overall structure but may be fuzzy about details.

5. When I am learning something new, it helps me to

a) talk about it.

b) think about it.

6. If I were a teacher, I would rather teach a course

a) that deals with facts and real life situations.

b) that deals with ideas and theories.

7. I prefer to get new information in

a) pictures, diagrams, graphs, or maps.

b) written directions or verbal information.

8. Once I understand

a) all the parts, I understand the whole thing.

b) the whole thing, I see how the parts fit.

9. In a study group working on difficult material, I am more likely to

a) jump in and contribute ideas.

b) sit back and listen.

10. I find it easier

a) to learn facts.

b) to learn concepts.

11. In a book with lots of pictures and charts, I am likely to

a) look over the pictures and charts carefully.

b) focus on the written text.

12. When I solve math problems

a) I usually work my way to the solutions one step at a time.

b) I often just see the solutions but then have to struggle to figure out the steps to get to them.

13. In classes I have taken

a) I have usually gotten to know many of the students.

b) I have rarely gotten to know many of the students.

14. In reading nonfiction, I prefer

a) something that teaches me new facts or tells me how to do something.

b) something that gives me new ideas to think about.

15. I like teachers

a) who put a lot of diagrams on the board.

b) who spend a lot of time explaining.

16. When I'm analysing a story or a novel

a) I think of the incidents and try to put them together to figure out the themes.

b) I just know what the themes are when I finish reading and then I have to go back and find the incidents that demonstrate them.

17. When I start a homework problem, I am more likely to

a) start working on the solution immediately.

b) try to fully understand the problem first.

18. I prefer the idea of

a) certainty.

b) theory.

19. I remember best

a) what I see.

b) what I hear.

20. It is more important to me that an instructor

a) lay out the material in clear sequential steps.

b) give me an overall picture and relate the material to other subjects.

21. I prefer to study

a) in a study group.

b) alone.

22. I am more likely to be considered

a) careful about the details of my work.

b) creative about how to do my work.

23. When I get directions to a new place, I prefer

a) a map.

b) written instructions.

24. I learn

a) at a fairly regular pace. If I study hard, I'll "get it."

b) in fits and starts. I'll be totally confused and then suddenly it all "clicks."

25. I would rather first

a) try things out.

b) think about how I'm going to do it.

26. When I am reading for enjoyment, I like writers to

a) clearly say what they mean.

b) say things in creative, interesting ways.

27. When I see a diagram or sketch in class, I am most likely to remember

a) the picture.

b) what the instructor said about it.

28. When considering a body of information, I am more likely to

a) focus on details and miss the big picture.

b) try to understand the big picture before getting into the details.

29. I more easily remember

a) something I have done.

b) something I have thought a lot about.

30. When I have to perform a task, I prefer to

a) master one way of doing it.

b) come up with new ways of doing it.

31. When someone is showing me data, I prefer

a) charts or graphs.

b) text summarizing the results.

32. When writing a paper, I am more likely to

a) work on (think about or write) the beginning of the paper and progress forward.

b) work on (think about or write) different parts of the paper and then order them.

33. When I have to work on a group project, I first want to

a) have "group brainstorming" where everyone contributes ideas.

b) brainstorm individually and then come together as a group to compare ideas.

34. I consider it higher praise to call someone

a) sensible.

b) imaginative.

35. When I meet people at a party, I am more likely to remember

a) what they looked like.

b) what they said about themselves.

36. When I am learning a new subject, I prefer to

a) stay focused on that subject, learning as much about it as I can.

b) try to make connections between that subject and related subjects.

37. I am more likely to be considered

a) outgoing.

b) reserved.

38. I prefer courses that emphasize

a) concrete material (facts, data).

b) abstract material (concepts, theories).

39. For entertainment, I would rather

a) watch television.

b) read a book.

40. Some teachers start their lectures with an outline of what they will cover. Such outlines are

a) somewhat helpful to me.

b) very helpful to me.

41. The idea of doing homework in groups, with one grade for the entire group,

a) appeals to me.

b) does not appeal to me.

42. When I am doing long calculations,

a) I tend to repeat all my steps and check my work carefully.

b) I find checking my work tiresome and have to force myself to do it.

43. I tend to picture places I have been

a) easily and fairly accurately.

b) with difficulty and without much detail.

44. When solving problems in a group, I would be more likely to

a) think of the steps in the solution process.

b) think of possible consequences or applications of the solution in a wide range of areas.

APPENDIX A2: FSILSQ Scoring Sheet Instructions

Put “1”s in the appropriate spaces in the table below (e.g. if you answered “a” to Question 3, put a “1” in Column “a” by Question 3).

Total the columns and write the totals in the indicated spaces.

For each of the four scales, subtract the smaller total from the larger one. Write the difference (1 to 11) and the letter (a or b) with the larger total.

For example, if under “ACT/REF” you had 4 “a” and 7 “b” responses, you would write “3b” on the bottom line under that heading (3b = 7b- 4a, and the “b” total was the larger of the two).

ACTIVE/REFLECTIVE			SENSING/INTUITIVE			VISUAL/VERBAL			SEQUENTIAL/GLOBAL		
Q	a	b	Q	a	b	Q	a	b	Q	a	b
1			2			3			4		
5			6			7			8		
9			10			11			12		
13			14			15			16		
17			18			19			20		
21			22			23			24		
25			26			27			28		
29			30			31			32		
33			34			35			36		
37			38			39			40		
41			42			43			44		
Total (sum "X" 's in each column)											
ACTIVE/REFLECTIVE			SENSING/INTUITIVE			VISUAL/VERBAL			SEQUENTIAL/GLOBAL		
	a	b		a	b		a	b		a	b
(Larger — Smaller) + Letter of Larger (see below*)											

*Example: If you totalled 3 for ‘a’ and 8 for ‘b’, you would enter 5b.

Explanation of scores

- If your score on a scale is 1-3, you have a mild preference for one or the other dimension but you are essentially well balanced. (For example, a 3a in the ACT/REF category indicates a mild preference for active learning).

- If your score on a scale is 5-7, you have a moderate preference for one dimension of the scale and will learn more easily in a teaching environment which favours that dimension.

- If your score on a scale is 9-11, you have a strong preference for one dimension of the scale. You may have real difficulty learning in an environment which does not support that preference.

Index Of Learning Styles – Report of Results

ACT												**REF**
	11a	9a	7a	5a	3a	1a	1b	3b	5b	7b	9b	11b	
SEN												**INT**
	11a	9a	7a	5a	3a	1a	1b	3b	5b	7b	9b	11b	
VIS												**VRD**
	11a	9a	7a	5a	3a	1a	1b	3b	5b	7b	9b	11b	
SEQ												**GLO**
	11a	9a	7a	5a	3a	1a	1b	3b	5b	7b	9b	11b	

- If your score on a scale is 1-3, you are fairly well balanced on the two dimensions of that scale.

- If your score on a scale is 5 or 7, you have a moderate preference for one dimension of the scale and will learn more easily in a teaching environment which favours that dimension.

- If your score on a scale is 9 or 11, you have a very strong preference for one dimension of the scale. You may have real difficulty learning in an environment which does not support that preference.

Example of a scoring sheet

	ACTIVE/REFLECTIVE			SENSING/INTUITIVE			VISUAL/VERBAL			SEQUENTIAL/GLOBAL	
Q	**a**	**b**	**Q**	**a**	**b**	**Q**	**a**	**b**	**Q**	**a**	**b**
1	1	0	**2**	1	0	**3**	1	0	**4**	1	0
5	1	0	**6**	0	1	**7**	1	0	**8**	1	0
9	1	0	**10**	1	0	**11**	0	1	**12**	1	0
13	1	0	**14**	1	0	**15**	1	0	**16**	1	0
17	1	0	**18**	1	0	**19**	1	0	**20**	1	0
21	1	0	**22**	0	1	**23**	0	1	**24**	1	0
25	1	0	**26**	0	1	**27**	1	0	**28**	1	0
29	1	0	**30**	0	1	**31**	0	1	**32**	1	0
33	0	1	**34**	1	0	**35**	0	1	**36**	1	0
37	0	1	**38**	1	0	**39**	0	1	**40**	1	0
41	0	1	**42**	1	0	**43**	0	1	**44**	1	0
	Total for each category										
	ACTIVE	**REL**		**SENSING**	**INTUITIVE**		**VISUAL**	**VERBAL**		**SEQ**	**GLOBAL**
	a	b		a	b		a	b		a	b
	8	3		7	4		5	6		11	0
Larger - smaller) + letter of larger = learning style preference											
	5a			3a			1b			11a	

APPENDIX A3: Letter from Felder: Granting Permission to use the FSILS Questionnaire

CERTIFICATION OF INTENTION TO USE THE *INDEX OF LEARNING STYLES* FOR EDUCATIONAL OR RESEARCH PURPOSES AT NO COST TO USERS

I certify that:

- I am affiliated with an educational institution and plan to administer the Index of Learning Styles only as part of my teaching, advising, staff development, and/or research activities with that institution.
- I will not charge a fee to anyone who completes the questionnaire under my direction or the direction of anyone working with me.
- I will keep the response sheet with the scoring key for the instrument strictly confidential. I will not share copies of it with anyone not directly involved with administering the instrument, and I will collect completed copies from everyone who takes the instrument.

Signature: 

Name: SAKYIWAA DANSO

Institution: UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG, SOUTH AFRICA

Email: bettydanso@yahoo.com / 45257574@mylife.unisa.ac.za/

1443569@students.wits.ac.zz

Please email the signed form to rmfelder@mindspring.com

or mail it to

Education Designs, Inc.
101 Lochside Drive
Cary, NC 27518-7401

APPENDIX B1: CCSSE Observation Form



Subject Teacher

Length of subject Length of observation

Observer Date

Subject matter of lesson

Learning Organisation and Management					
1. During the observed class session (s), to what extent did the teacher demonstrate the following behaviours?					
	Completely	Adequately	Minimally	Not at all	Not applicable
a. Started and ended class on time. Comment….	O	O	O	O	O
b. Was prepared to conduct class. Comment…….	O	O	O	O	O
c. Ensured that learners were engaged in the learning activities. Comment….	O	O	O	O	O
d. Noticed when a learner or learners were not engaged and took action to involve the learners in the class activity Comment….	O	O	O	O	O
e. Clearly explanied the learning objectives for the class session . Comments	O	O	O	O	O
f. Summarises the major points at the end of the lesson Comment…	O	O	O	O	O
Knowledge of Subject Matter					
2. During the observed class session (s), to what extent did the teacher demonstrate the following behaviours?					
a. Explained concepts clearly Comments…	O	O	O	O	O
b. Gave “real-world” examples to illustrate concepts Comments…	O	O	O	O	O
c. Responded adequately to student questions Comments..	O	O	O	O	O

Teaching Style					
3. During the observed class session(s), to what extent did the instructor demonstrate the following behaviors?					
a. Spoke clearly and audibly Comments…	O	O	O	O	O
b. Showed enthusiasm for the subject matter and teaching Comments..	O	O	O	O	O
c. Treated all students in an equitable manner Comments…	O	O	O	O	O
d. Encouraged questions and student participation Comments…	O	O	O	O	O
e. Gave students an adequate amount of time to respond to questions Comments….	O	O	O	O	O
f. Provided feedback that gave students direction for improvement Comments…	O	O	O	O	O
g. Interacted with individual students during the class session Comments…	O	O	O	O	O
h. Interacted with students working in small groups during the class session Comments…	O	O	O	O	O
i. Elicited feedback validation of student understanding of the material Comments….	O	O	O	O	O
j. Used techniques that reflect an awareness of different learning styles Comments….	O	O	O	O	O
k.Appropriately used Web-based resources, PowerPoint, or other technological tools Comments…	O	O	O	O	O
l. Encouraged or required students' engagement in out-of-class activities related to the course (e.g., work with other students, participation in campus events, service learning, email communication with other students, etc.) Comments…	O	O	O	O	O
Instructional Techniques					
4. During the observed class session(s), what percentage of time was spent on each of the following instructional techniques?					
a. Lecture Comments…		0 - 19% O	20 - 39% O	40 -74% O	75 - 100% O
b. Teacher-led discussion Comments…		O	O	O	O
c. Teacher-student shared responsibility (seminar, discussion) Comments…		O	O	O	O
d. Student computer use Comments….		O	O	O	O
e. Small group activities Comments….		O	O	O	O
f. Student presentations Comments…		O	O	O	O
g. Hands-on practice Comments…		O	O	O	O
h. In-class writing Comments…		O	O	O	O
i. Performance (in applied and fine arts, etc.) Comments…		O	O	O	O
j. Experiential learning (labs, fieldwork, internships, etc.)		O	O	O	O

j. Experiential learning (labs, fieldwork, internships, etc.)		O	O	O	O
Comments…					
k. Assessment activities		O	O	O	O
Comments…					
Encouragement to Engage in Critical Thinking					
5. During the observed class session(s), to what extent did the learning process designed by the instructor encourage					
a. Memorizing facts, ideas, methods so that they can be repeated in pretty much the same form.	O	O	O	O	O
Comments…					
b. Analyzing the basic elements of an idea, experience, or theory	O	O	O	O	O
Comments..					
c. Synthesizing and organizing of ideas, information, and experiences in new ways	O	O	O	O	O
Comments..					
d. Judging value or soundness of information, arguments, or methods	O	O	O	O	O
Comments…					
e. Applying theories or concepts to practical problems in new situations	O	O	O	O	O
Comments…					
Overall					
6. Overall, did the instructor create an engaging learning experience during the observed class session?					
a. Comments...	O	O	O	O	O
Observer Signature:			Date		
Teacher's Comments….					
Teacher's Signature			Date		

APPENDIX B2: Permission to use the CCSSE Observation Tool

1 message

Mike Bohlig bohlig@cccse.org Thu, 07 Feb 2017 at 15:49

To: Sakyiwaa Danso <1443569@students.wits.ac.za>

Good morning Sakyiwaa,

Thank you for contacting the Center about using the classroom observation form. With this email, I give you permission to use this form for your dissertation. Use beyond your dissertation is also granted as this form is in the public domain and the Center only requests appropriate citation when used.

Good luck with your dissertation.

Mike.

E. Michael Bohlig, Ph.D. | Assistant Director of Research

Center for Community College Student Engagement

Program in Higher Education Leadership

Department of Educational Leadership and Policy

College of Education

The University of Texas at Austin

3316 Grandview Street

Austin, Texas 78705

512-232-6456

512-471-4209 (fax)

bohlig@cccse.org

www.cccse.org

APPENDIX C: Learner Interview Questions

Learners interview about learners' cultural background, learning styles and instructions.

Gender: _____ Learner Code: _____

Instructions

The aim of this questionnaire is to solicit in-depth knowledge about the instructional materials used by the teacher during Physical Sciences instructions. Your answers will help me and your teacher to understand what we can do to help you understand Physical Sciences lessons better.

PART A

1. How you learn the most in the Physical Sciences classroom

a. In what way(s) do you learn the most in the Physical Sciences classroom?

b. How are you motivated to learn better in the Physical Sciences classroom?

c. What are the things that detract (weaken) you from doing well in your Physical Sciences lessons?

2. How physical science learning experiences with the use of learning style-based instructional strategies help you in learning science.

a. How did learning style-based instructional strategies impact on your interest, motivation and achievement in physical sciences?

b. In what ways has the personal perception of your ability in physical sciences been impacted by learning style based instructional strategies?

c. What impact did learning style based instructional strategies have on your perception of physical sciences as a subject?

3. The type and nature of Physical Sciences instructional materials (teaching strategies) used by your Physical Sciences teacher which highly influence your Physical Science performance.

(a) Describe the characteristics of instructional materials which influence your current performance in Physical Sciences as explained by their emphasis given to:

i. Practical activities……

ii. Conceptual and theoretical explanation of physical sciences……..

iii. Diagrammatic, model and mathematical representations of physical sciences concepts……

iv. Textual explanations (words) presentation of physical sciences……..

4. The essential characteristics of Physical Sciences instructional materials that you consider most helpful to your current performance in Physical Sciences, if not mentioned yet.

(a) From the Physical Sciences teaching-learning materials such as textbooks, computer simulations, and chats, what instructional materials do you consider most helpful during your current performance in Physical Sciences, put them in their order of importance to you?

(b) Please list Physical Sciences instructional materials (teaching learning materials) which you consider least helpful to your current performance?

PART 2

5. How learners' home background influence their learning preferences.

(a) How do you learn the most at home?

(b) Do you see any difference between home learning and school science learning?

(c) Do you think your home background has any influence on your learning? Why do you think so?

(d) Describe how your home background does influence your learning in the Physical Sciences class room?

APPENDIX D: Teacher Interview Questions

Protocol for teacher interviews on teaching instructions

Interview schedules for use at the beginning of the study

Participant's (teacher) profile

Demographic information

Date	Age:	Gender:
Qualification		
Specialisation		
Teacher experience		
Grade(s) taught		
Learning area		
Number of Learners	Male:	Female:

I have renamed my research participants (teachers) as: ……..

Place of residence: Mthatha Location: suburb□ Township: □

Race:

Language(s) spoken:

Position in school:

Other duties in school:

Means of transport to school: Own car □ Stuff transport □ Taxi □ Scholar transport□

Your views about teaching and learning:

Brief description of yourself regarding your profession:

Classroom management skills: Yes □ No □

Cooperative learning: Yes □ No□

Cultural diversity: Yes □ No□

Higher order thinking skills: Yes □ No□

Performance based assessment: Yes □ No□

Research question	Why is the information needed	Main questions	Follow up questions	Prompts/probes
3	To establish if and how teachers use instructions in the physical science classroom	How do you use instructions in the science classroom?	(a) What type of teaching method do you normally use in your instructions and why do you use such a method in teaching? (b) Does the method of instruction take into account the learners' cultural background and learning styles? How? (c) How do you relate your instructional strategies to the performance of learners in Physical Sciences?	a) okay b) tell me more

			(d)What are the main factors that you think affect teaching and learning of Physical Sciences in the science classroom?	
3	To obtain teacher's views on the use of traditional teacher-centred teaching strategy	What is your view on the use of teacher centred teaching strategy?	(a)What is your understanding of teacher-centred instruction? (b) For what type of lesson would you find this teaching strategy most useful? (c) Can you tell me why this method of teaching is commonly used by science teachers? (d) What are the challenges of using this method of teaching?	Do you think it will work?
3	To obtain teacher's views of the use of differentiated instructions.	What is your understanding of the use of varied instructions in	What might be similar/ different between the teacher-centred instruction and the use of differentiated	a) Why not? b) Is it practical?

		the science classroom?	instructions in the science classroom?	

Thank you for your time!!!!!!!!

Interview questions for the Physical Sciences teachers

Interview on physical sciences instructions (teaching strategies) to answer research question 2 and 4.

Instructions

The aim of this questionnaire is to solicit in-depth knowledge about the instructional materials used by the teacher during Physical Sciences instructions. Your answers will help me to understand what I can be doing better to help you in your Physical Sciences teaching.

PART 1: Knowledge about learning styles

1. What are learning styles?
2. What are your views about the implementation of learning style based instructions in the Physical Sciences classroom?
3. Do you think the implementation of learning style-based instructional strategies led to increased performance among learners? How?
4. What are the challenges that you faced with regards to the implementation of learning style-based instructional strategies in the physical science classroom?
5. What kind of support have you received from your school when implementing the learning style-based instructional strategies in the physical science classroom?
6. What do you suggest be done in the Physical Sciences classroom to enhance learner performance?

PART 2: Cultural influence on learning styles

7. What is your understanding of culture?

8. Does your cultural background have an impact on your teaching?
9. What is your opinion regarding how culture affect your teaching?
10. What is your opinion regarding how culture would affect the learning of your learners?
11. Do you think there is a relationship between culture and science?
12. Is there an intersection between culture and gender?
13. Is there an intersection between culture and teaching styles?
14. How do you use culture as a lens to change the teaching learning processes in your physical science classroom?

Thank you very much for your time!!!!

APPENDIX E1: Physical Science Achievement Test Questionnaire (PSAT)

NAME:_____

GENDER:_____

GRADE:_____TYPE OF LEARNING STYLE;_____

MULTIPLE – CHOICE QUESTION (2 points each) (50 Minutes)

INSTRUCTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Choose the answer and write only the letter (A-D) next to the question number (1-50) in the ANSWER BOOK, for example 1. B.

1. A current carrying conductor placed in a magnetic field experiences a force, the direction of the force depends on:

   (a) The direction of the current flow

   (b) The switch

   (c) The type of conductor used

   (d) The strength of the magnet

2. Which of the following devices are based on the principles that a current carrying conductor in a magnetic field experiences a force?

(a) A relay

(b) A DC motor

(c) A coil

(d) An electromagnet

3. An EMF is induced when

(a) The electric flux threading a coil changes

(b) The magnetic flux threading coil changes

(c) The galvanometer is connected to a device

(d) The magnet is held stationary.

4. When the north pole of a magnet is pushed into a coil connected to galvanometer, the needle

(a) Moves to the left

(b) Moves to the right

(c) Stays still

(d) Moves down

5. The electric field experienced by a point charge is $800N.C^{-1}$ at a distance of 30m from the centre of the sphere. The charge carried by the sphere is...

(a) 26.7 nC

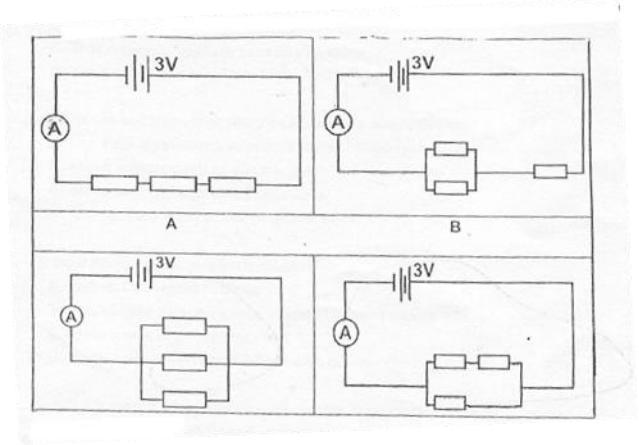
(b) 375 nC

(c) 8 nC

(d) 4 nC

6. A learner is provided with three identical resistors to insert in any manner in a circuit.

Which ONE of the following circuit diagrams will allow the largest current through the Ammeter?



7. The size of the induced EMF depends on;

   (a) Rate of change of magnet flux with respect to time

   (b) Rate of change of electric flux with respect to time

   (c) Rate of change of voltage with respect to time

   (d) Rate of change of induced current

8. The principle of operation of an electromagnetic relay is

   (a) A current flowing through a conductor produces a concentric magnetic field

   (b) A current flowing through a conductor produces a concentric electric field

   (c) A changing magnetic field includes a current

   (d) A changing electric field induces a current

9. The electrostatic force F between two charged particles is positive. Which ONE of the following is CORRECT?

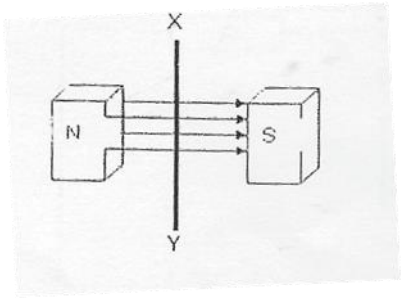
   (a) The magnitudes of the two charges are equal

(b) One charge is positive while the other is negative.

(c) The electrostatic force between the charges is attractive

(d) The electrostatic force between the charges is repulsive.

10. A conducting wire, XY, moves between two magnets as shown below.



Which ONE of the following actions can lead to an increased induced current in wire XY? Move the wire…..

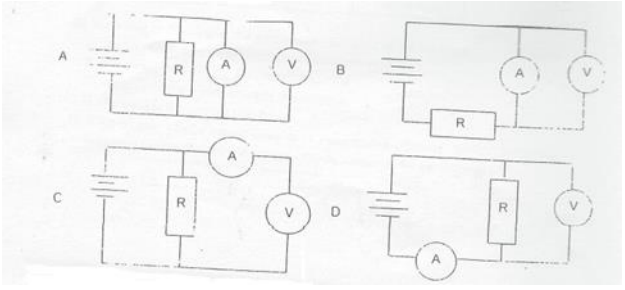
(a) Quickly and parallel to the magnetic field.

(b) Slowly and parallel to the magnetic field.

(c) Quickly and perpendicular to the magnetic field

(d) Slowly and perpendicular to the magnetic field.

11. A learner wants to measure the current in and the potential difference across a resistor R in a circuit. In which ONE of the following circuits will the learner be able to take these readings?



12. What force would result if the north poles of two magnets were brought near one another?

    (a) Repulsion

    (b) Attraction

    (c) Friction

    (d) Compaction

13. What can iron filings sprinkled on a piece of paper with a magnet under the paper show you?

    (a) That current can flow through the filings

    (b) That paper distorts magnetism

    (c) That magnetic fields are counter clockwise

    (d) The pattern of a magnetic force field

14. How can you show that electricity creates a magnetic field?

    (a) Use a compass near a wire with current flowing through it

    (b) Move wire through an electric field

    (c) Move wire through a magnetic field

    (d) Connect a battery to the magnetic field

15. How do you make an electromagnet?

    (a) Connect a magnet to battery

    (b) Run current through a wire wrapped around an iron rod

    (c) Place a wire in a magnetic field

(d) Place a wire in a magnetic field with current flowing through it

16. What happens when you turn off current in an electromagnet?

(a) The magnetism is lost

(b) The current keeps flowing because of the magnetic force

(c) The electromagnet loses its polarity

(d) The electromagnet becomes a generator

17. The area surrounding a magnet that exerts a force on all magnetic materials located near

(a) Electric field

(b) Magnetic poles

(c) Magnetic field

(d) Electric flux

18. Can you generate electricity with a magnet?

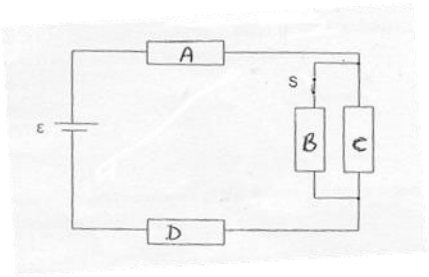
(a) No, because only friction on electric charges or batteries create electricity

(b) Yes, by moving a wire thorough a magnetic field

(c) Yes, by putting a current through a wire around a magnet

(d) Yes, because magnets use electricity to stay effective

19. The four resistors, A, B, C and D in the circuit below are identical. The cell has an emf e, and is initially closed. Switch S is not opened.



Switch S is now OPENED. Which ONE of the following combinations of changes will occur in P, Rand T?

	CURRENT IN A	CURRENT IN C	CURRENT IN D
a	Decreases	Remains the same	Decreases
b	Increases	Remains the same	Increases
c	Increases	Increases	Increases
d	Decreases	Increases	Decreases

20. According to Ohm's law, the greater the resistance of the resistors

    (a) The weaker the potential difference across the resistors

    (b) The greater the current that flows

    (c) The greater the temperature of the material

    (d) The weaker the current that flows

21. A bar magnet can be moved towards or away from a solenoid. Which ONE of the following factors/actions will increase the deviation on the galvanometer?

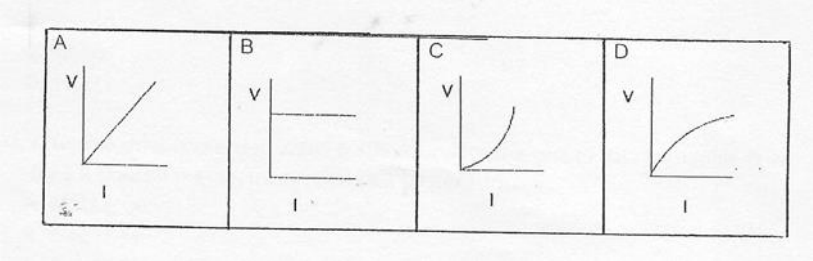
    (a) Use a solenoid with a smaller diameter.

    (b) Use a solenoid with fewer turns.

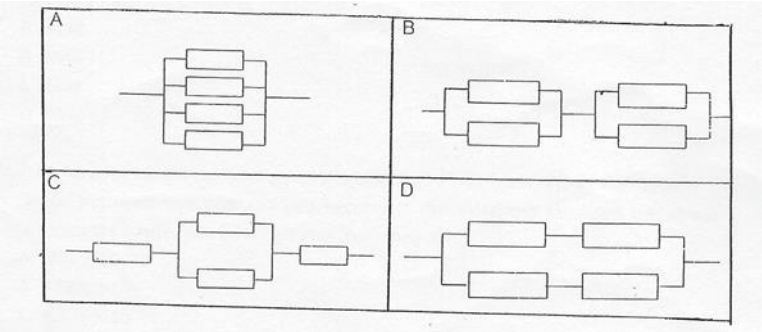
(c) Use a weaker magnet

(d) Move the magnet faster towards and away from the solenoid

22. Which one of the following graphs correctly represents the relationship between potential difference (V) and current (I) for an Ohmic conductor?



23. Each of the four identical resistors is connected to the same emf. Which ONE of the following circuits will have the highest resistance?



24. A 30W light bulb is left on for 8hours overnight. How much energy was wasted?

(a) 28800 J

(b) 864000 J

(c) 54390 J

(d) 784000 J

25. The rate at which electrical energy is converted in an electric circuit

(a) Power

(b) Magnetic flux

(c) Charge

(d) Resistance

26. Which law states that the amount of current through a conductor; at constant temperature, is proportional to the voltage across the resistor?

(a) Coulomb's Law

(b) Len's Law

(c) Faraday's Law

(d) Ohm's Law

27. Calculate the equivalent resistance of the following compositions; a 20 and a 30 resistors connected in parallel?

(a) 4Ω

(b) 5Ω

(c) 1.2Ω

(d) 3Ω

28. What is the symbol and unit for electric charge?

(a) F and N

(b) E and C

(c) Q and C

(d) q_e and K

29. How great is the elementary charge in an electron?

(a) $+1.2 \times 10^{-19}$ C

(b) $+1.6 \times 10^{-19}$ C

(c) $+2.4 \times 10^{19}$ C

(d) -1.3×10^{-19} C

30. Three (3) aluminium spheres X, Y and Z are placed on insulating stands as, shown. X is loaded with a positive charge of + 12uC and sphere Y with a negative charge of -4uC. Sphere Z is left unchanged, Give the final charge on X if X touches Y?

(a) -6uC

(b) -4uC

(c) +4uC

(d) +2uC

31. Give the relationship between force and distance?

(a) F is proportional to r.

(b) F directly proportional to r.

(c) F is inversely proportional to r.

(d) F increases, r increases

32. A tumble drier is marked: 220V; 600W, what is the resistance of the tumble drier?

(a) 80,670 Ω

(b) 65,50 Ω

(c) 98,40 Ω

(d) 45,60 Ω

33. A tumble drier is marked: 220V; 600W, calculate the cost to use the tumble drier for 3 ½ hours if the electricity cost is R1, 04 per kWh.

(a) R 2184, 00

(b) R 4321, 34

(c) R 1237, 00

(d) R3222, 33

34. The potential difference across an electric lamp is 12V and the current through it is 5A. Calculate the power of the lamp.

(a) 20W

(b) 50W

(c) 60W

(d) 90W

35. The force between two charged objects is 7 X10-4N. What is the magnitude of the force between the two charged objects if the distances between the charged objects are made four times greater than they are?

(a) 432 X 10^{-5}N

(b) 322 X 10^{-5}N

(c) 4,375 X 10^{-5}N

(d) 3,232X 10^{-5} N

36. In which direction will an electron move in an electric field?

(a) parallel to the field

(b) against the field

(c) away from the field

(d) perpendicular to the field

37. Calculate the electric field strength 30 cm from a +5nC charge.

(a) $8{,}53 \times 10^{-2}$ N.C $^{-1}$

(b) $16{,}3 \times 10^{-2}$ N.C $^{-1}$

(c) $23{,}5 \times 10^{-2}$ N.C^{-1}

(d) $4{,}99 \times 10^{-2}$ N.C^{-1}

The reading on an electricity meter shows that 30 kWh of energy have been supplied to a house during one day. [Use this information to answer question 38 - 39].

38. What is the average power consumption (per hour) of the house in this time?

(a) 4,3 kWh

(b) 7,3 kWh

(c) 1,25 kWh

(d) 9 kWh

39. Electricity is charged at 70c per kWh. How much is the electricity bill is for that day?

(a) R30.00

(b) R56.79

(c) R21.00

(d) R43.34

40. Which three factors influence the magnitude of the induced current in the cell?

(a) Temperature, number of turns and strength of the material.

(b) Speed of motion of the magnet, temperature, and kind of material.

(c) Type of material, temperature, and number of turns.

(d) Strength of magnet, number of turns and speed at which magnet moves

41. A solenoid with 450 turns has a sectional area of $5cm^2$.It is placed perpendicular in a uniform magnetic field of 0,01T. Calculate the influx through the solenoid?

    (a) 6×10^{-6} Wb

    (b) 5×10^{-6} Wb

    (c) 7×10^{-6} Wb

    (d) 1.0×10^{-6} Wb

42. A magnetic field of 0.5 T moves through a loop of $10cm^2$. The field lines are at an angle of 70° with the surface of the loop. What is the magnitude of the angle between the field and the normal on the plane of the wire loop?

    (a) 20°

    (b) 30°

    (c) 40°

    (d) 50°

Three resistors of respectively 50, 100 and 350 are connected in series to a 100 power source. [Use the information to answer question: 43; 44; 45].

43. Determine the equivalent resistance of the circuit?

    (a) 430 Ω

    (b) 500 Ω

    (c) 3540 Ω

    (d) 120 Ω

44. Determine the current passing through the circuit

(a) 2A

(b) 15A

(c) 9A

(d) 6A

45. Determine the potential difference across the 350 resistor by making use of Ohm's law?

    (a) 530V

    (b) 40V

    (c) 20V

    (d) 70V

If the magnitude of the electrostatic force between two charges is equal to F_1, determine the magnitude of the force between the charges if….[Use this information to answer questions: 46; 47 and 48]

46. The magnitude of one of the charges is doubled.

    (a) F becomes 4 times smaller

    (b) F becomes 8 times smaller

    (c) F becomes 2 times greater

    (d) F becomes 8 times greater

47. The distance between the charges is doubles

    (a) F becomes 8 times greater

    (b) F becomes 4 times smaller

    (c) F becomes 6 times greater

    (d) F becomes 2 times smaller.

48. The magnitude of tone of the charges is halved while the distance between them is doubled.

    (a) F becomes 8 times smaller

    (b) F becomes 4 times greater

    (c) F becomes 6 times smaller

    (d) F becomes 12 times greater

49. Deduce the SI Unit of the proportionality constant in the Coulomb equation?

    (a) $N.m^{-2}$

    (b) m^{-2}

    (c) nq_e

    (d) $N.m^2.C^{-1}$

50. Two sphere with masses of 200g each, carry charges of +3uC and +4uC respectively. Their centers are 300 m apart. Calculate the electrostatic force between the two spheres?

    (a) 1, 2 N repelling

    (b) 2,2N attraction

    (c) 3,2 N repelling

    (d) 4,2 N attraction

APPENDIX E2: PSAT Answer sheet

Learner information				
Name				
Grade				
Gender				
Learning style				
Total marks				
Question number	Answer		Question number	Answer
1			26	
2			27	
3			28	
4			29	
5			30	
6			31	
7			32	
8			33	
9			34	
10			35	
11			36	
12			37	
13			38	
14			39	
15			40	
16			41	
17			42	
18			43	
19			44	
20			45	
21			46	
22			47	
23			48	
24			49	
25			50	

APPENDIX E3: PSAT Memo

A	26. D
1. B	27. C
2. B	28. C
3. B	29. B
4. C	30. C
5. C	31. C
6. C	32. A
7. A	33. A
8. D	34. C
9. C	35. C
10. B	36. C
11. A	37. D
12. D	38. C
13. A	39. C
14. C	40. D
15. C	41. B
16. B	42. A
17. B	43. B
18. D	44. A
19. D	45. D
20. D	46. C
21. A	47. B
22. C	48. A
23. B	49. D
24. A	50. A

APPENDIX F: Permission from Wits University Human Research Ethics Committee (Non-Medical) Ethics Clearance Letter

Wits School of Education

WITS UNIVERSITY

27 St Andrews Road, Parktown, Johannesburg, 2193 Private Bag 3, Wits 2050, South Africa. Tel: +27 11 717-3064 Fax: +27 11 717-3100 E-mail: enquiries@educ.wits.ac.za Website: www.wits.ac.za

Date: 29 March 2016

Student Number: 1443559

Protocol Number: 2016ECE004D

Dear Sakyiwaa Danso

Application for Ethics Clearance: Doctor of Philosophy

Thank you very much for your ethics application. The Ethics Committee in Education of the Faculty of Humanities, acting on behalf of the Senate, has considered your application for ethics clearance for your proposal entitled:

Exploring students' academic achievements in physical sciences through learning styles and learning style based instructional materials in Mthatha high schools

The committee recently met and I am pleased to inform you that clearance was granted.

Please use the above protocol number in all correspondence to the relevant research parties (schools, parents, learners etc.) and include it in your research report or project on the title page.

The Protocol Number above should be submitted to the Graduate Studies in Education Committee upon submission of your final research report.

All the best with your research project.

Yours sincerely,

M Mashiyi

Wits School of Education

011 717-3416

cc Supervisor – Dr Emmanuel Mushayikwa

APPENDIX G: Permission from Eastern Cape Department of Education (ECDE)

Province of the
EASTERN CAPE
EDUCATION

STRATEGIC PLANNING POLICY RESEARCH AND SECRETARIAT SERVICES
Steve Vukile Tshwete Complex • Zone 6 • Zwelitsha • Eastern Cape
Private Bag X0032 • Bhisho • 5605 • REPUBLIC OF SOUTH AFRICA
Tel: +27 (0)40 608 4773/4035/4537 • Fax: +27 (0)40 608 4574 • Website: www.ecdoe.gov.za

Enquiries: NY Kanjana Email: nykanjana@live.co.za Date: 06 April 2016

Ms Sakyiwaa Danso

P.O. Box 52548

Mthatha

5100

Dear Ms Danso

PERMISSION TO UNDERTAKE A DOCTORAL STUDY: EXPLORING STUDENTS' ACADEMIC ACHIEVEMENTS IN PHYSICAL SCIENCES THROUGH LEARNING STYLES AND LEARNING STYLE BASED INSTRUCTIONAL STRATEGIES IN MTHATHA SCHOOLS

1. Thank you for your application to conduct research.
2. Your application to conduct the above mentioned research in four High Schools under the jurisdiction of Mthatha District of the Eastern Cape Department of Education (ECDoE) is hereby approved based on the following conditions:
    a. there will be no financial implications for the Department;
    b. institutions and respondents must not be identifiable in any way from the results of the investigation;
    c. you present a copy of the written approval letter of the Eastern Cape Department of Education (ECDoE) to the Cluster and District Directors before any research is undertaken at any institutions within that particular district;
    d. you will make all the arrangements concerning your research;
    e. the research may not be conducted during official contact time, as educators' programmes should not be interrupted;
    f. should you wish to extend the period of research after approval has been granted, an application to do this must be directed to Chief Director: Strategic Management Monitoring and Evaluation;

APPENDIX H1: Sample of letter of request for principals' permission to conduct the study in their schools

LETTER TO THE PRINCIPALS,

DATE:

Dear Principal,

My name is Sakyiwaa Danso. I am a PhD student in the School of Education at the University of the Witwatersrand.

I am doing research on: Exploring students' academic achievements in electricity and magnetism through learning styles and learning style based instructional materials in Mthatha high schools.

My research firstly involves observing your Physical Sciences teachers' instructions in the classroom and interviewing them afterwards. In addition, Grade 11 Physical Sciences learners will be required to complete a questionnaire so I can identify their learning styles in the science classroom. Secondly, the Physical Sciences teachers will be trained on the development and implementation of learning style-based instructional strategies for three days. Teachers will be video-taped during the training sessions to record their responses to the activities presented. After the training, the teachers will then implement learning style-based instruction in their Physical Sciences classrooms for teaching electricity/magnetism for six weeks. The teachers' lessons will be observed during this intervention. Thirdly, before the start of the classroom unit on electricity / magnetism, learners will be given a pre-test highlighting common misconception on the topic. After the implementation of the instructional strategies, learners will be required to complete a post-test on the same topic. Based on the results on the questionnaire, selected learners will be interviewed to find out more details about their thoughts on the use of learning style-based instructions in the Physical Sciences classroom. During this section, learners will be audio recorded (with permission from the learners and guardians). Learners will be selected for interviews on the basis of their performance in pre-, post- and learning style questionnaires. The Physical Science teachers will also be interviewed to know their views about the learning style-based instructions. The reason why I have chosen your school is because, your school and mine belong to the same district cluster, and I know most of your Physical Sciences teachers. We

have worked collaboratively before. In addition, your grade 11 classes have the right number of learners for this study.

I am therefore inviting your school to participate in this research study over the next three months.

The Physical Sciences learners and their teacher will not be advantaged or disadvantaged in any way. They will be reassured that they can withdraw their permission at any time during this project without any penalty. There are no foreseeable risks in participating in this study. The participants will not be paid for this study.

The names of the research participants and identity of the school will be kept confidential at all times and in all academic writing about the study. When referring to activities or participant responses, pseudonyms will be used. Any videos captured, will be pixelated to remove identifiable features. No photography of humans will be used. Your individual privacy will be maintained in all published and written data resulting from the study.

All research data will be stored for three to five years on a password-protected sector of a hard drive on the password-protected desktop in my supervisor's office at WITS and will be destroyed thereafter.

Please let me know if you require any further information. I look forward to your response as soon as is convenient.

Yours sincerely,

NAME: Sakyiwaa Danso

ADDRESS: 16 Jizana Street,
Northcrest,
Mthatha, 5100
OR
School of Education
Department of Science and Mathematics Education
University of the Witwatersrand

EMAIL: 1443569@students.wits.ac.za

TELEPHONE NUMBERS: 0737586444

APPENDIX H2: Information Sheet for Physical Science Learners

DATE:

Dear Learner

My name is Sakyiwaa Danso and I am a PhD student in the School of Education at the University of the Witwatersrand.

I am doing research on Exploring Students' academic Achievements in electricity and magnetism through Learning Styles and Learning Style Based Instructional Materials in Mthatha High Schools.

I would like to study how you respond to your teacher's instructions in physical science. I would like to understand how the way you learn is shaped by the way you are taught and what impact this has on your achievement. Firstly, you will be given a questionnaire that identifies how you naturally learn, so that I can identify your style of learning. Secondly, you will also get a pre-test on electricity and magnetism, so that I can capture your previous knowledge on this topic. Your teacher will then teach the unit on electricity/magnetism using learning style-based instructional strategies. During this session, I will be observing your teacher's lessons. This will start in July, 2016 and will last for three months. After the unit has been taught, you will be required to write a test based on electricity/magnetism to know your level of understanding of the unit. Based on the analysis of the test, I would like to interview some of you. The interviews will be audio-recorded so that I do not miss any important information you may have to give. Your class has been selected for this study because your Physical Science teacher has agreed to participate in the study.

I was wondering whether you would mind agreeing to take part in this interesting study, and thus I need your help with the completion of the questionnaires and interviews.

Although the study will take place during your Physical sciences lessons, and you will be expected to attend all classes and participate in the two tests, your participation in completing the learning style-based questionnaire is completely voluntary, which means that you don't have to do it. In addition, you can withhold your marks for the pre-test and the post-test, so that they will not be captured for the study. You can also request not to be observed during

the classroom observations. All this is completely fine and you will not be disadvantaged in any way. If you decide halfway through that you prefer to stop participating, this is also fine, and completely your choice. You will not be affected negatively in any way.

I will not be using your own name but I will make one up so no one can identify you. All information about you will be kept confidential in all my writing about the study. Also, all collected information will be stored safely at WITS and will be destroyed between 3-5 years after I have completed my project.

I am attaching an informed consent form. I would like you to take it home, discuss with your guardian and complete it, then bring it back to me. I have also enclosed a similar information sheet and consent form for your guardian, so that they can also discuss with you and complete the form. Can you please bring both forms with you to school, when you and your parents have completed them. However, remember that at the end of the day it is your decision to join us in the study.

I look forward to working with you!

Please feel free to contact me if you have any questions.

Thank you

Miss Sakyiwaa Danso

ADDRESS: 16 Jizana Street

Northcrest, Mthatha, 5100. 16 Jizana Street,

Mthatha, 5100

OR

EMAIL: 1443569@students.wits.ac.za

TELEPHONE NUMBERS: 0737586444

APPENDIX H3: Learner Consent Form

Please fill in the reply slip below if you agree to participate in my study called: Exploring Students' academic Achievements in electricity and magnetism through Learning Styles and Learning Style Based Instructional Materials in Mthatha High Schools.

My name is: _____

Permission for questionnaires Circle one

I agree to fill in and complete the questionnaire for this study YES/NO

Permission to be audiotaped during interviews

I agree to be audiotaped during the interview or observation lesson YES/NO

I know that the audiotapes will be used for this project only YES/NO

Permission to be interviewed

I would like to be interviewed for this study. YES/NO

I know that I can stop the interview at any time and don't have to

answer all the questions asked. YES/NO

Permission for test / questionnaire

I agree to complete a questionnaire and tests for this study. YES/NO

Informed Consent

I understand that:

- my name and information will be kept confidential and safe and that my name and the name of my school will not be revealed.
- I do not have to answer every question and can withdraw from the study at any time.
- I can ask not to be audiotaped, photographed and/or videotaped
- all the data collected during this study will be stored in a safe place and destroyed within 3-5 years after completion of my project.

Sign_____ Date_____

APPENDIX H4: Information Sheet Parents

DATE:

Dear Parent

My name is Sakyiwaa Danso and I am a PhD student in the School of Education at the University of the Witwatersrand.

I am doing research on Exploring Students' academic Achievements in electricity and magnetism through Learning Styles and Learning Style Based Instructional Materials in Mthatha High Schools.

I would like to study how your child responds to his/her teacher's instructions in physical science. I would like to understand how the way your child learns is shaped by the way he/she is taught and what impact this has on his/her achievement. Firstly, your child will be given a questionnaire that identifies how he/she naturally learns, so that I can identify his/her style of learning. Secondly, your child will also get a pre-test on electricity and magnetism, so that I can capture his/her previous knowledge on this topic. Your child's teacher will then teach the unit on electricity/magnetism using learning style-based instructional strategies. During this session, I will be observing your child's teacher's lessons. This will start in July, 2016 and will last for three months. After the unit has been taught, your child will be required to write a test based on electricity/magnetism to know his/her level of understanding of the unit. Based on the analysis of the test, I would like to interview some of the grade 11 learners, and your child may be one of them. The interviews will be audio-recorded so that I do not miss any important information that he/she may have to give. Your child's school and class have been selected for this study, because his/her teacher has agreed to participate in this study.

I was wondering whether you would allow your child to take part in this interesting study.

Although the study will take place during your child's Physical sciences lessons, and he/she will be expected to attend all classes and participate in the two tests, his/her participation in completing the learning style-based questionnaire is completely voluntary, which means that he/she will not have to do it if he/she does not want to. In addition, your child can withhold his/her marks for the pre-test and the post-test, so that they will not be captured for the study.

Your child can also request not to be observed during the classroom observations. All this is completely fine and your child will not be disadvantaged in any way. If your child decides halfway through that he/she prefers to stop participating, this is also fine, and completely his/her choice. He/she will not be affected negatively in any way.

I will not be using your child's own name but I will make one up so no one can identify him/her. All information about him/her will be kept confidential in all my writing about the study. Also, all collected information will be stored safely at WITS and will be destroyed between 3-5 years after I have completed my project.

I am attaching an informed consent form. I would like to ask you to discuss with your child, and complete it, then give your child to bring it back to me. I have also enclosed a similar information sheet and consent form for your child, so that he/she can also discuss with you and complete the form. However, remember that at the end of the day it is your child's decision to join us in the study.

I look forward to working with you!

Please let me know if you require any further information.

Thank you very much for your help.

Yours sincerely,

Miss Sakyiwaa Danso

ADDRESS: 16 Jizana Street,
Northcrest,
Mthatha, 5100
OR
School of Education
Department of Science and Mathematics Education
University of the Witwatersrand
EMAIL: 1443569@students.wits.ac.za
TELEPHONE NUMBERS: 0737586444

APPENDIX H5: Parent's Consent Form

Please fill in and return the reply slip below indicating your willingness to allow your child to participate in the research project called: ***Exploring Students' academic Achievements in electricity and magnetism through Learning Styles and Learning Style Based Instructional Materials in Mthatha High Schools*.**

I, _____ the parent of _____

Permission to observe my child in class

I agree that my child may be observed in class. YES/NO

Permission to be audiotaped

I agree that my child may be audiotaped during interview. YES/NO

I know that the audiotapes will be used for this study only YES/NO

Permission to be interviewed

I agree that my child may be interviewed for this study. YES/NO

I know that he/she can stop the interview at any time and doesn't have to

answer all the questions asked. YES/NO

Permission for questionnaire/test

I agree that my child may complete questionnaires and write a test for this study. YES/NO

Informed Consent

I understand that:

- my child's name and information will be kept confidential and safe and that my name and the name of my school will not be revealed.
- he/she does not have to answer every question and can withdraw from the study at any time.
- he/she can ask not to be audiotaped, photographed and/or videotape
- all the data collected during this study will be stored in a safe place and destroyed within 3-5 years after completion of my project.

Sign_____ Date_____

APPENDIX H6: Information Sheet Teachers

DATE:

Dear Teacher,

My name is Sakyiwaa Danso. I am a PhD student in the School of Education at the University of the Witwatersrand.

I am doing research on: Exploring students' academic achievements in electricity and magnetism through learning styles and learning style based instructional materials in Mthatha high schools.

My research firstly involves observing Physical Sciences teachers' instructions in the classroom and interviewing them afterwards. In addition, Grade 11 Physical Sciences learners will be required to complete a questionnaire so I can identify their learning styles in the science classroom. Secondly, the Physical Sciences teachers will be trained on the development and implementation of learning style-based instructional strategies for two days. Teachers will be video-taped during the training sessions to record their response to the activities presented. After the training, the teachers will then implement learning style-based instruction in their Physical Sciences classrooms for teaching electricity/magnetism for six weeks. The teachers' lessons will be observed during this intervention. Thirdly, before the start of the classroom unit on electricity / magnetism, learners will be given a pre-test highlighting common misconception on the topic. After the implementation of the instructional strategies, learners will be required to complete a post-test on the same topic. Based on the results on the questionnaire, selected learners will be interviewed to find out more details about their thoughts on the use of learning style-based instructions in the Physical Sciences classroom. During this section, learners will be audio recorded (with permission from the learners and guardians). Learners will be selected for interviews on the basis of their performance in pre-, post- and learning style questionnaires. The Physical Science teachers will also be interviewed to know their views about the learning style-based instructions. The reason why I have chosen you is because, your school and mine belong to the same district cluster, and we have worked collaboratively before. In addition, your grade

11 classes have the right number of learners for this study.

I am therefore inviting you to participate in this research study over the next three months.

You and your Physical Sciences learners will not be advantaged or disadvantaged in any way. You can withdraw your participation (and that of your learners) at any time during this project without suffering any disadvantage. There are no foreseeable risks in participating in this study. The participants will not be paid for this study.

The names of the research participants and identity of the school will be kept confidential at all times and in all academic writing about the study. When referring to activities or participant responses, pseudonyms will be used. Any videos captured, will be pixelated to remove identifiable features. No photography of humans will be used. Your individual privacy will be maintained in all published and written data resulting from the study.

All research data will be stored for three to five years on a password-protected sector of a hard drive on the password-protected desktop in my supervisor's office at WITS and will be destroyed thereafter.

Thank you very much for your help.

Yours sincerely,

SIGNATURE

Sakyiwaa Danso
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Northcrest,
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University of the Witwatersrand

EMAIL: 1443569@students.wits.ac.za

TELEPHONE NUMBERS: 0737586444

APPENDIX H7: Teacher's Consent Form

Please fill in and return the reply slip below indicating your willingness to be a participant in my voluntary research project called: ***Exploring Students' academic Achievements in electricity and magnetism through Learning Styles and Learning Style Based Instructional Materials in Mthatha High Schools.***

I, _____ give my consent for the following:

Permission to observe you in class

I agree to be observed in class. YES/NO

Permission to be audiotaped

I agree to be audiotaped during the interview or observation lesson YES/NO

I know that the audiotapes will be used for this project only YES/NO

Permission to be interviewed

I would like to be interviewed for this study. YES/NO

I know that I can stop the interview at any time and don't have to

answer all the questions asked. YES/NO

Permission to be videotaped

I agree to be videotaped during the workshop. YES/NO

I know that the videotapes will be used for this project only. YES/NO

Informed Consent

I understand that:

- my name and information will be kept confidential and safe and that my name and the name of my school will not be revealed.

- I do not have to answer every question and can withdraw from the study at any time.
- I can ask not to be audiotaped, photographed and/or videotape
- all the data collected during this study will be destroyed within 3-5 years after completion of my project.

Sign_____ Date_____

APPENDIX I: The teachers' workshop: The professional development plan

This 3 –day workshop was organised for physical science teachers sampled for the study. The aim of the workshop is to enhance teachers' knowledge of learning style preferences among physical science learners and to provide alternative means of teaching learners according to their individual learning style preferences.

DAY 1

The first day of the workshop was devoted to enable teachers to understand the concept of learning styles.

Learning outcomes: By the end of the workshop, physical science teachers should be able to:'

- Explain the concept of learning styles and explain their importance in the physical science classroom.
- Describe how the knowledge of learning styles can contribute to learner academic success in the physical science classroom.
- Identify their own learning style preferences.

The workshop was opened with a prayer which was said by the researcher. The researcher subsequently welcomed the teachers and introduced the facilitators to the workshop.

This was followed by a presentation of the day.

Resources were allocated to teachers on learning styles and learning style-based instructions.

DAY 2

Day two of the workshop was devoted to the development of instructional materials in a form of discussion.

Learning outcomes: By the end of the workshop, teachers should be able to:

- develop instructional materials for teaching science concepts in high school, considering the differences learners bring to the science classroom.

- perform at least one activity on electricity and magnetism

DAY 3

The third day of the workshop was focused on lesson preparations and group presentations. Each presentation was followed by feedback from the researcher and the audiences.

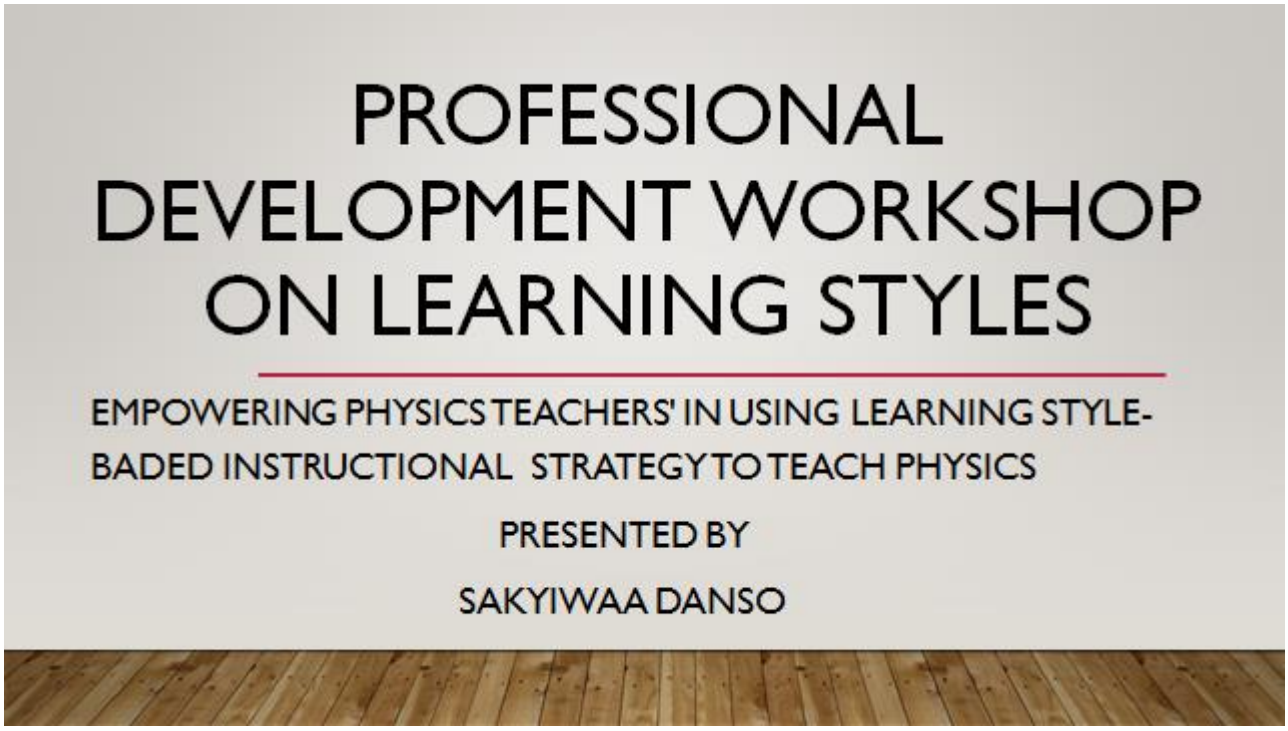
Learning outcome: by the end of the workshop, physical science teachers will be able to:

- prepare lesson plans with the focus of aligning learners' learning styles to teaching methods.
- Group reports and presentations

Materials for day 3:

Flip charts, PowerPoint presentations, handouts, markers of various colours, visual aids and audio aid devices.

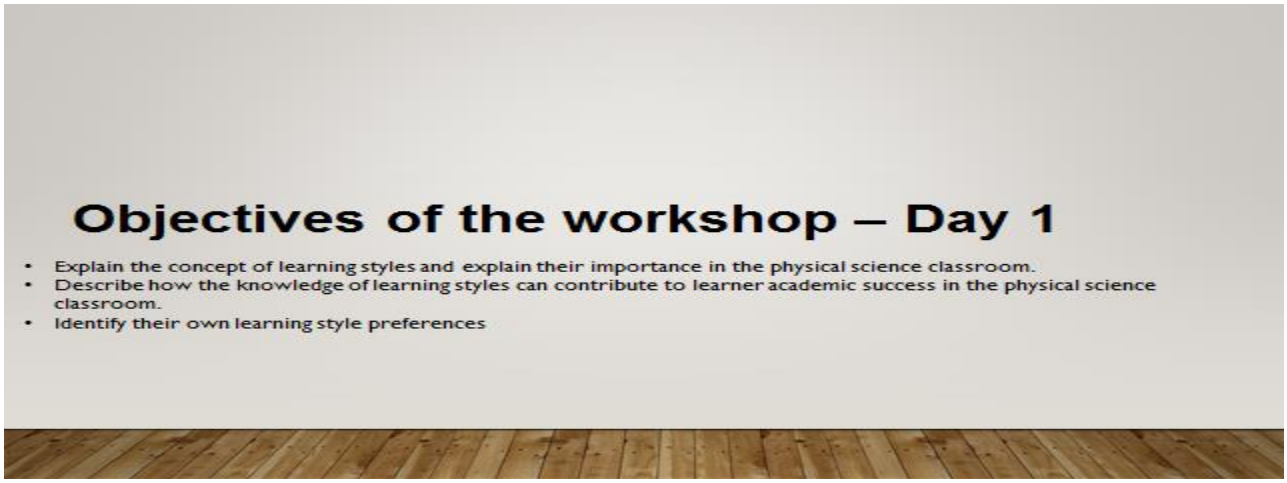
DAY I: Presentation by researcher



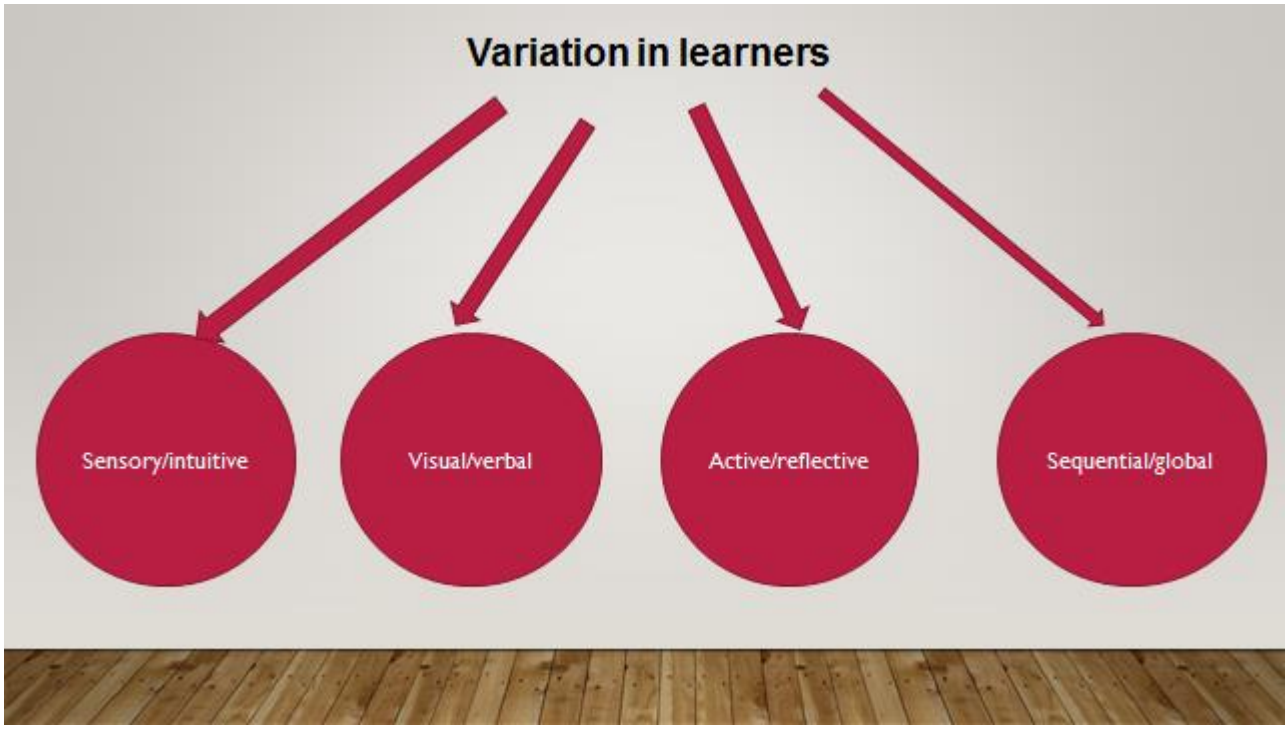
Sub notes:

Welcome and introduction by the researcher. A brief purpose of the workshop was highlighted by the researcher, with the assistance of the cluster leader and the subject advisor.

Slide 2: Objective of the workshop was highlighted by the researcher



Slide 3: The researcher presents workshop of learning styles



This was followed by a discussion by the group and then the teachers answered questions to identify their learning styles.

A short break was taken by the participant and thereafter, a discussion was made on the need to identify learning styles.

Summary and preview was made by the researcher which was followed by the closure of the workshop for day 1.

Day 2

The researcher discusses with the group how diversed teaching instructions could be fully engaged in all learners in a physical science classroom.



The researcher facilitates the concept of developing the learning style-based instructional strategies. The focus is on different learning styles, different teaching styles and alignment of teaching style to learning styles.



Scenarios of role play as a teaching methodology, brainstorming, discussion, group work, experimentation,

After the first break, the district subject advisor facilitate the conduct of practical activity in electricity and magnetism.

Demonstration activity:

To plot the current / voltage characteristics of metal rods (copper and aluminium) and to calculate their resistivity.

To determine the resistance of various connecting cords by plotting their current / voltage characteristics and calculating the contact resistances.

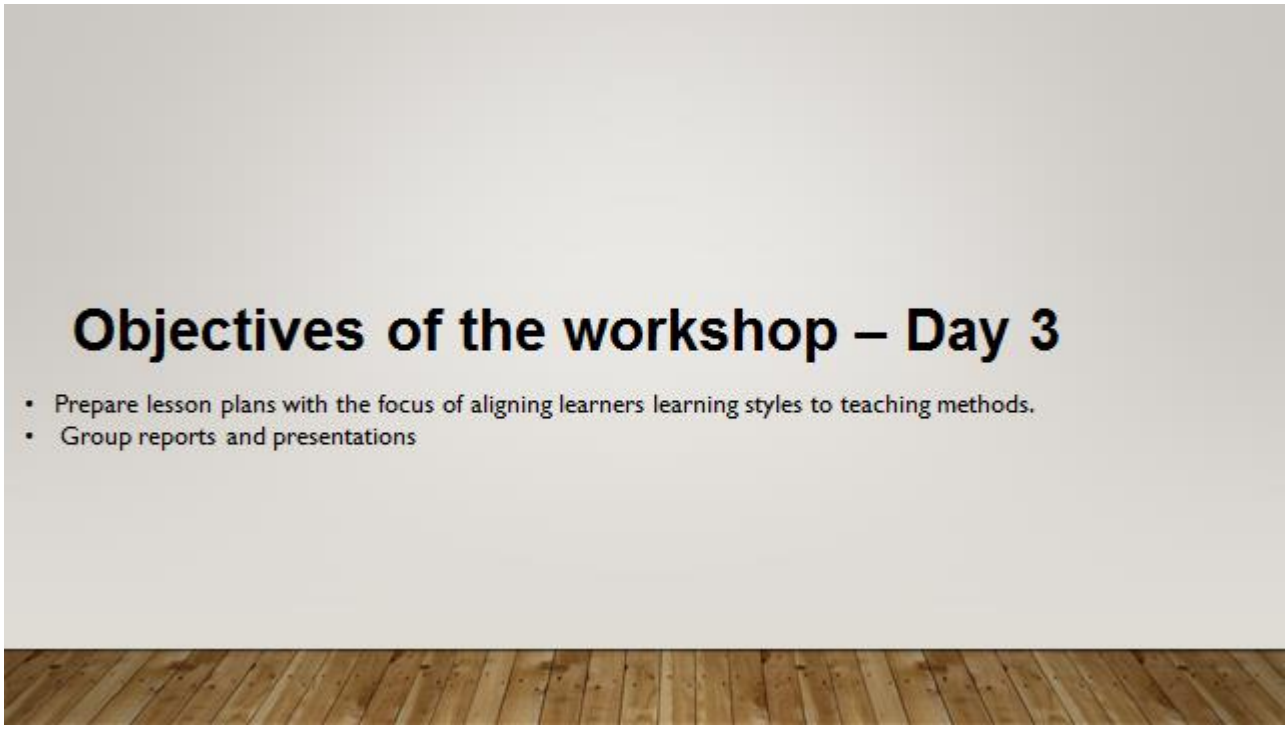




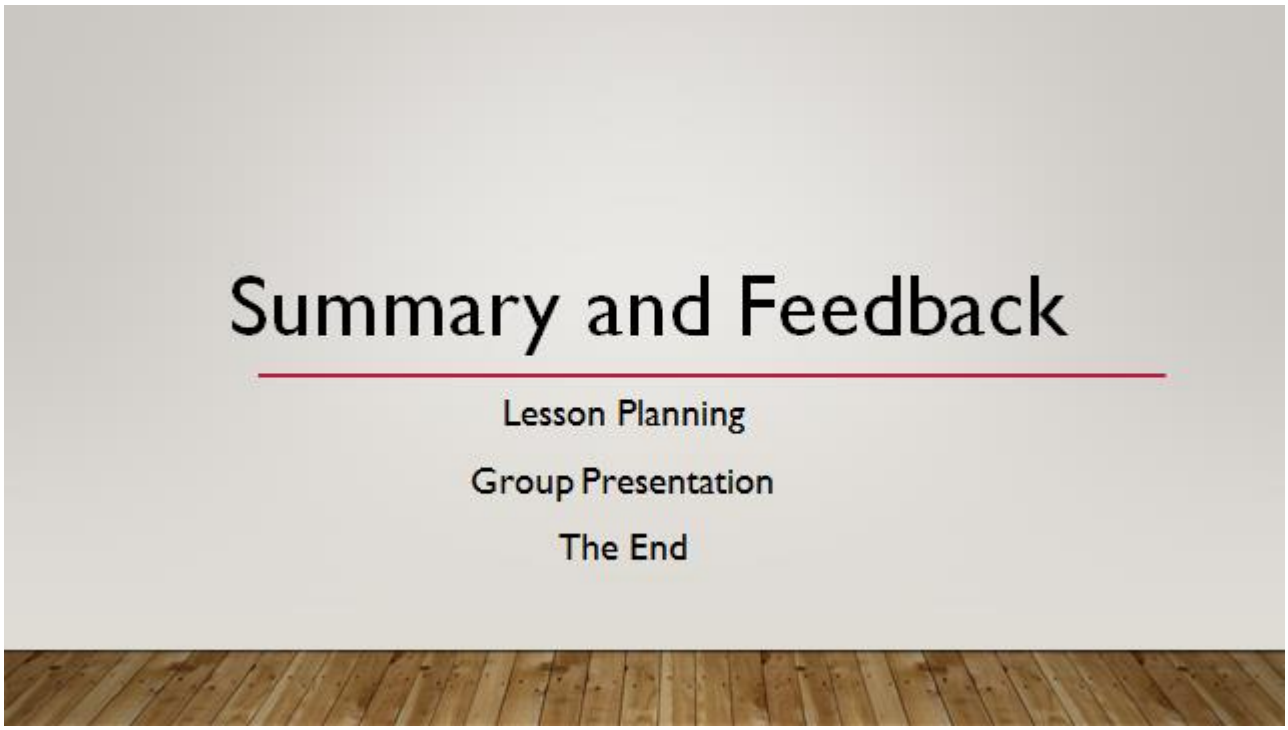
Day 3:

Lesson plan preparations. The researcher leads the discussion on planning lessons on electricity and magnetism, considering learner differences and aligning to teaching styles.

The participants are put into groups to prepare lessons and formulate their group presentations.



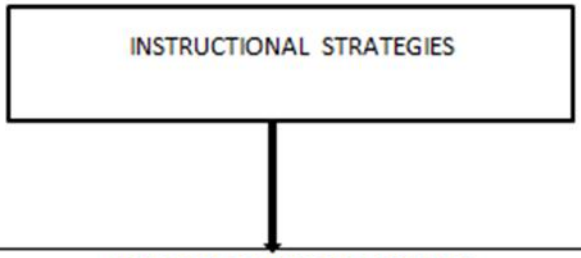
Groups deliver their lesson presentations. The audience give feedback on each group presentation.



The researcher leads the participates to evaluate the workshop and give feedback on the workshop.

APPENDIX J: Development of instructional materials

		LEARNING STYLES							
		Sensitive	Intuitive	Visual	Verbal	Active	Reflective	Sequential	Global
TEACHING STRATEGIES	Demonstration/Experimentation	x		x		x			
	Games and simulations		x	x		x			
	Learning based on problem solving	x				x			
	Role playing		x			x			x
	Presentation	x		x			x	x	
	Discussion panel		x		x	x			
	Brainstorming				x	x			x
	Case study		x				x		x
	Question and Answer Method	x			x		x	x	
	Project Method		x			x			x



LEARNING STYLE DIMENSIONS			
Input (LSD 1- Active/Reflective)	Processing (LSD 2- Sensory/Intuitive)	Perception (LSD 1 - Visual/Verbal)	Understanding (LSD4- Sequential/Global)
Lecture method. Group discussion. Brain storming Demonstration	Problem-solving Hands-on Games/ Simulations Case study Open-ended questions.	Games and Simulations Demonstrations Provide concrete examples. Problem-solving strategies (guided discovery and inquiry).	Demonstration strategy. Practical exercises involving drilling. Creativity exercises.

Details of learning style-based instructional materials

No	Topic	Instructions for active/reflective learners	Instructions for sensing/intuitive learners	Instructions for visual/verbal learners	Instructions fosequential/global learners	Resources
1	Coulomb's Law	Presentation, discussion	Project based method	demonstrations/ discussion	role paly, project based	Simulations from computers
2	Electric fields	model discussion	case study	model/discussion method	case study/brain storming	power supply, wire, retort stand, cardboard, several compasses
3	Magnetic fields associated with conductor	Demonstration/ Hands-on activity	question and answer/group activity	games and simulations	role play, case study	iron, nail, thin insuated copper, more D-cell batteries, paper clips
4	Faraday's Law	Project based method	Use of highligther activity	demonstration, chart, power point presentation,	presentation/ brainstorming	solenoid, bar magnet, galvanometer, connecting wires.
5	Ohm's law	Project based method/ presentation	experimenation, activity based method	demonstration/ games and simulations/ brainstorming	case study/brain storming	Light bult, resistor, ammeter, voltmeter, wires
6	Power, and Energy	project based, hands-on activities	experimenation, activity based method	demonstration	case study/brain storming	bulbs, batteries, conducting wires, crocodile clips, bulb-holder, ammeters, voltmeters

APPENDIX K: Lesson Plans:

Writing a Lesson Plan for learning style based instructions

By the end of this workshop, participating teachers should be able to:

- create guidelines for planning each part of a lesson
- determine effective teaching techniques
- utilize planning templates provided

What is a lesson?

An organized set of activities designed to present one piece of your course while working toward achieving one or more learning objective.

The parts and flow of a lesson

Every lesson is a complete segment that you create for the purposes of new learning. Keep your students in mind as you plan a lesson and ask these questions:

Who are my learners?

How do they receive and process information?

What do they already know?

Why should they learn about this?

What must they learn?

What must they do to learn?

The parts, or stages, of the lesson determine what the teacher and learners do. Regardless of activity or lecture, each lesson should build on the last and flow seamlessly into the next.

Using the appropriate technique

The techniques you plan to use in your lessons depend on:

- The types of learners in your class (learning style differences) and their previous knowledge.
- The type of learning you are aiming for. Some of the possibilities are listed below.
- The physical teaching environment and the available equipment and resources

To convey information, use:

- discussion
- field trips
- demonstration
- role play
- games and simulation
- problem solving
- brainstorming
- case study
- question and answer
- project method
- hands-on activities

Guidelines for making a lesson plan

It is important to recognize the different aspects of instruction at the different stages of the lesson. When preparing a lesson plan, use the following checklist:

At the start, I plan to:

1. Review prior learning and learner/teacher expectations_____

2. Make the learning outcomes clear_____

3. Use a lead-in to capture learners interest and engage them in learning_____

Halfway, I plan to:

1. Apply strategies to actively involve learners in the learning process_____

2. Utilize a variety of media to illustrate concepts and processes_____

3. Make sure that the lesson flows easily and logically_____

4. Confirm that learners are learning material that is meaningful and new_____

5. Facilitate opportunities for practice and feedback_____

6. Review and build on related material_____

At the end, I plan to:

Provide the proper closure students find important. To do this, I will:

1. Assess what learners have learned_____

2. Summarize the lesson_____

3. Relate the lesson to real life and/or the next lesson_____

LESSON PLANS

Subject: Physical sciences

Grade: 11

Number of learners: 35

Duration: 1 hour

Student Learning Objectives: by the end of the lesson, learners should be able to :

- to explain how electric current can generate a magnetic field.
- Students will be able to create an electromagnet.
- Students will be able to apply the concept of the electromagnet in the creation of a telegraph.
- Students will be able to explain how electricity and magnetism work together in electric motors and generators.

Prior knowledge:

• Students have learned about electricity, electric circuits, voltage, and current in Grade 10.

• They are familiar with how to connect circuit elements.

• Electricity and magnetism are closely related.

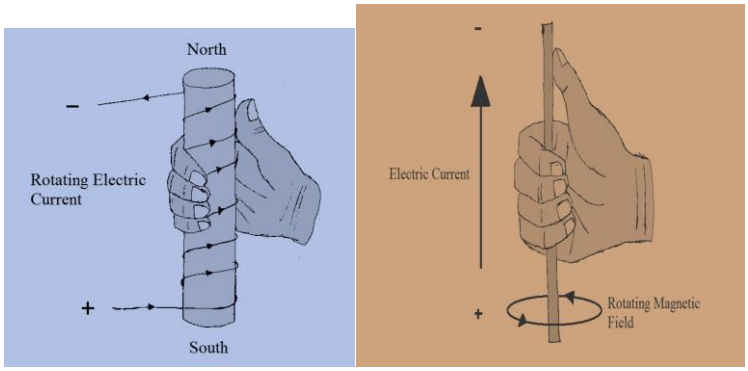
Teaching Plan

General Plan

- Part 1: Introduce electromagnetism
- Part 2: The electromagnet (with activity)

Concepts	Teacher's activity	Learners activity	Resources
Introduction	Teacher introduces the lesson by asking learners question. How do you create a magnet using electricity, how can you create electricity using a magnet? Let learners think about these questions as the lesson progresses.	Learners respond to the teacher's questions.	Chalkboard illustrations
Electromagnetism	Lesson Development: Teacher define electromagnetism as the fundamental relationship between electrical and magnetic fields (10mins)	learners respond to the teacher's questions and isten attentively to the teacher.	Chalkboard illustrations
Electromagnetism	Teacher explains that a moving electric field produces a magnetic field that rotates around it.	Learners listern and contribute to the discussion	Simulation
Electromagnetism	The teacher explains that a moving magnetic field produces an electric field that rotates around it.	Learners observe the electric field produced by the moving magnetic field.	Demonstrations
Right Hand Rule	The demonstrates The Right Hand Rule helps understand this. (Handout) (10 min.)	Learners work in groups to understand the Right Hand Rule.	Simulation
Battery terminals	The teacher explains with the aid of diagrams that positive electric current flows from the positive terminal of the battery to the negative terminal.	Learners discuss the activity after the demonstrations.	Demonstration, Charts, simulations
Magnetic field	The teacher describes a magnetic field to move from the North pole to the South pole.	Learners observe the simulations	Charts, simulations
The electromagnet	Teacher leads demonstration and let learners curl their fingers of your right hand in the direction of the rotating electric or magnetic field. Their thumb point in the direction of the resulting magnetic or electric field.	Learners take turns to curl their fingers around a solenoid in the direction of the electric/magnetic field.	Powerpoint presentations, solenoid, bar magnets.
The electromagnet	Teacher asks the class for some examples of what materials would be good for the core of the electromagnet.	Learners brainstorm and respond to the teachers questions.	• Steel, iron, anything that is attracted to a common refrigerator magnet
The electromagnet	Teacher gives several examples of wher electromagnets used.5mins	Learners brainstorm and respond to the teachers questions.	• Motors and generators • Doorbells, Speakers • Hard drives.
The electromagnet	Ask the class to come up with other examples of electromagnets around them. (5 min.)	Learners respond to the teachers questions.	Telephones, audio tapes,
The electromagnet	Break the class into groups and begin the Electromagnet Activity. (20 min.)Remember to reinforce the above concepts during the activity.	Group activity	Power Point Presentation Right Hand Rule Handout Electromagnet Activity and Related Materials
The electromagnet	Ask the students to use the right hand rule to describe what's going on with their nails and coils of wire (5mins).	Learners brainstorm and respond to the teacher's questions.	Power Point Presentation
The electromagnet	Ask them if they think a pencil will work as an electromagnet's core and why/why not. (5mins).	Learner brainstorm and respond to the teacher's question.	Right Hand Rule Handout, Electromagnet Activity and Related Materials.

Class activity



Part 2: The electromagnet

Resources

Electricity and Magnetism.ppt PowerPoint Presentation

Right Hand Rule Handout

Electromagnet Activity and Related Materials

(Optional) Telegraph Activity

(Optional) Electric Motor Activity and Related Materials

The Right Hand Rule

1. Examine the system. Is the magnetic field or the electric field rotating?

2. If it is the magnetic field that is rotating you probably have a straight wire. Point your thumb in the direction of the electric current. Remember, positive electric current goes out the positive end of the battery, through the wires, and back into the negative end!

3. With your thumb pointing in the correct direction, curl your fingers as in the left side of the figure below. This is the direction of the rotating magnetic field (clockwise or counter clockwise).

4. If it is the electric field that is rotating, you probably have a coil of wire. Figure out which way the electric current is rotating, again remembering that the current flows from the positive terminal of the battery to the negative.

5. Notice where your thumb is pointing. This is towards the North Pole of the resulting magnetic field, as in the right side of the figure.

Activity 2: Unshifted Activity: The Electromagnet

Purpose

The electromagnet is one of the most common electrical devices in use. They can be found in stereo speakers, headphones, DVD players, video recorders, wind turbines, and anything with an electric motor. The electromagnet is a great example of how electricity and magnetism are related. It also shows how this relation can convert electrical energy into mechanical energy.

Materials

• Battery with holder

• Switch

• Steel nail

• Pencil

• Several paper clips

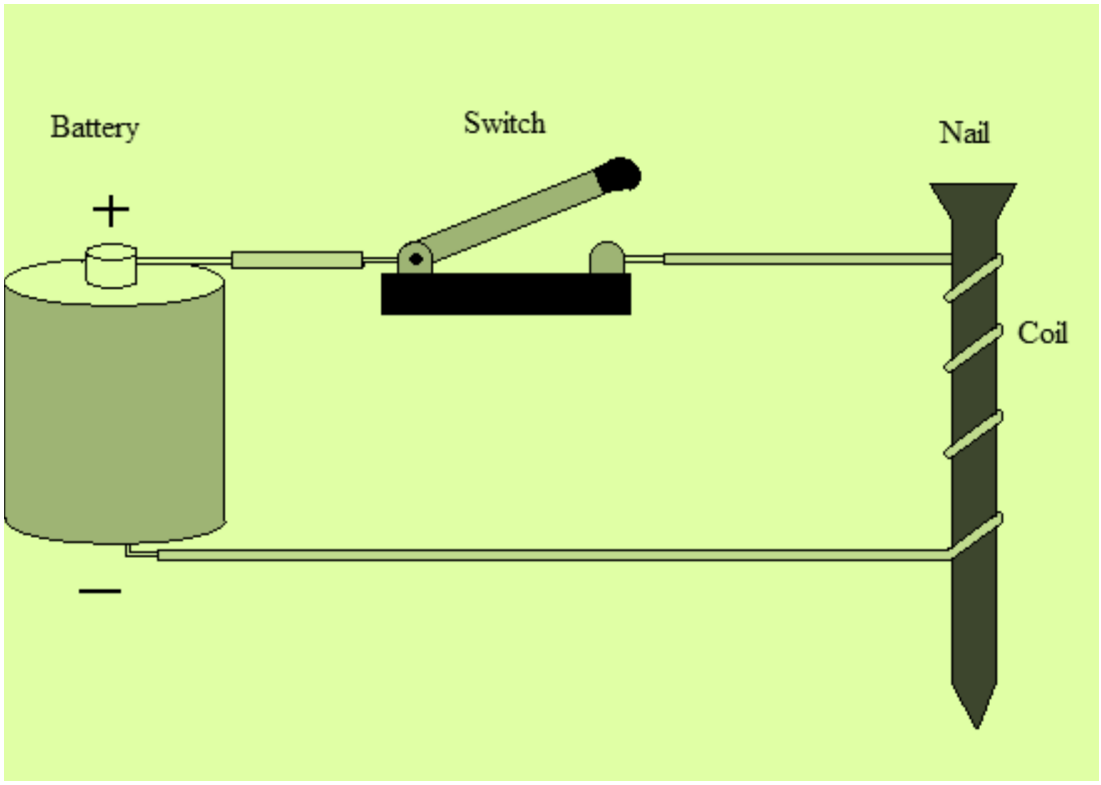
• Compass

• 2 feet of wire, insulated with exposed ends.

Procedure

1. Form groups and gather your materials as instructed by your teacher.

2. Make an electromagnet like the one shown in the figure.



Begin by wrapping your wire around your nail 10 times.

4. Turn on your electromagnet.

5. How many paper clips can you lift with the nail? ……..

6. Turn off your electromagnet.

7. Now try wrapping your wire around the nail as many times as possible, while still leaving room to connect to the battery.

8. How many turns were you able to get? ……

9. Turn on the electromagnet and try to lift the paperclips.

10. How many paperclips can you lift with the nail now? ……

11. Turn it off and replace the nail with a pencil, then turn it back on.

12. How many paperclips can you lift with the pencil?

Turn it off, and replace the pencil with your nail.

14. Using the right hand rule, predict which end of your nail is the North Pole.

15. Turn on your electromagnet and bring your compass near the point of the nail.

16. Is the point a North or South pole? ……

17. Turn off your electromagnet and switch your battery around, so the electric current will flow in the opposite direction.

18. Turn on your electromagnet and again bring the compass near the point of the nail.

19. Is the point North or South?

Discussion Questions

1. Explain how the number of turns in your coil affects the strength of your electromagnet.

_____

_____

_____

2. Was the electromagnet stronger with the nail or the pencil in its core? Why?

_____

_____

_____

3. Did reversing the battery change the electromagnet? How?

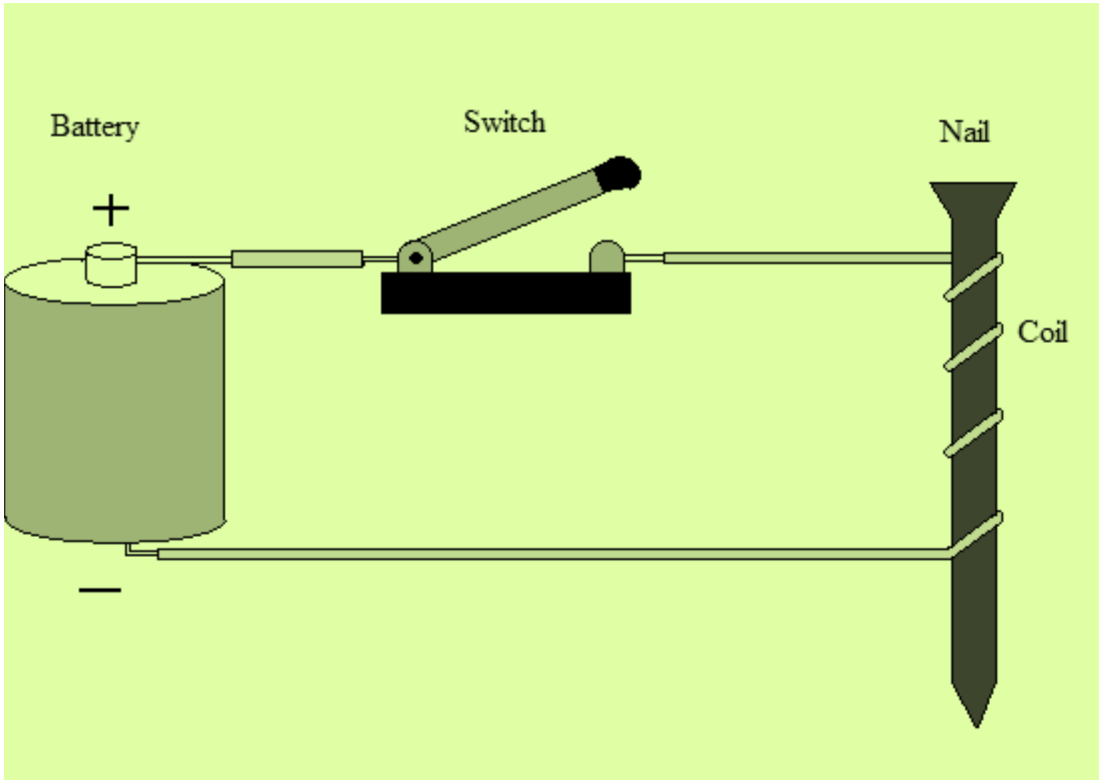
_____

_____

4. In the figure, label the North and South Poles of the electromagnet.

Also draw an arrow showing which direction the positive electric current

is flowing.



Activity 3: Shifted Activity: The Electromagnet

Purpose

The electromagnet is one of the most common electrical devices in use. They can be found in stereo speakers, headphones, DVD players, video recorders, wind turbines, and anything with an electric motor. The electromagnet is a great example of how electricity and magnetism are related. It also shows how this relation can convert electrical energy into mechanical energy.

Materials

• Battery with holder

• Switch

• Steel nail

• Pencil

• Several paper clips

• Compass

• 2 feet of wire, insulated with exposed ends

Directed Experiment

1. Form groups and gather your materials as instructed by your teacher.

2. Make an electromagnet like the one shown in the figure.

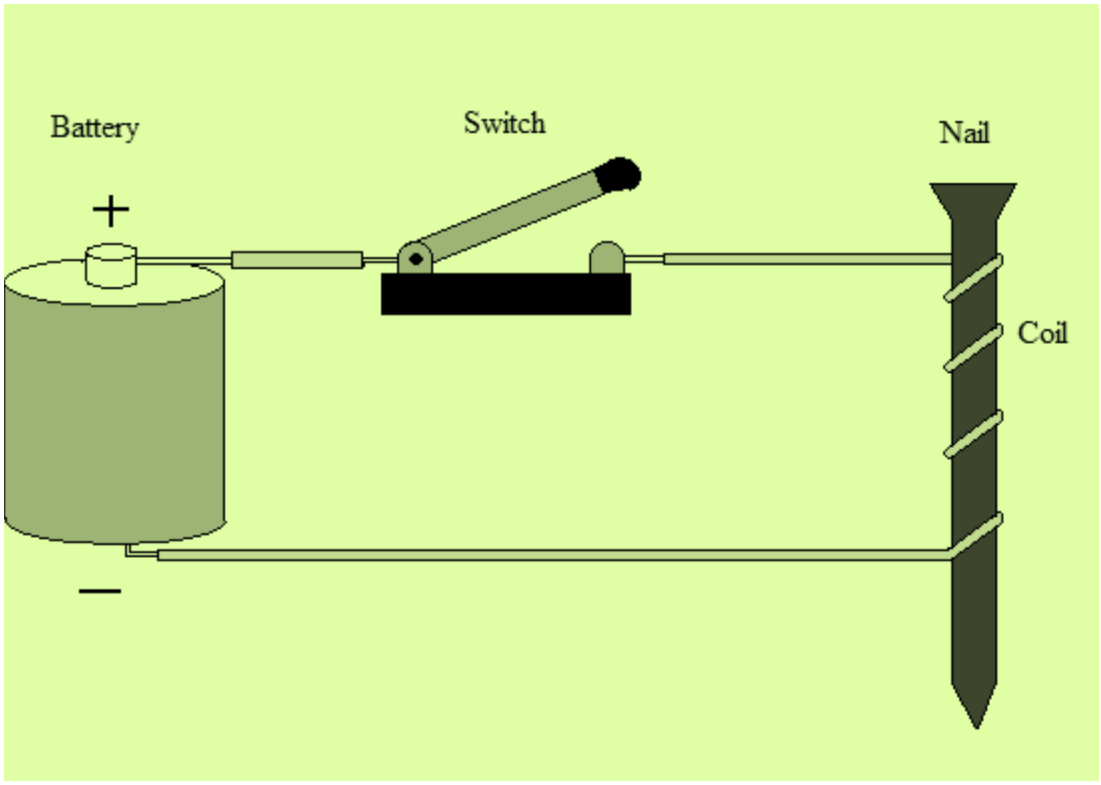
Note that the figure shows the wire wrapped around the nail 4 times. Continue wrapping your wire so there are 20 turns in your coil.

4. Use the switch so we don’t drain our batteries!

5. Connect your wires to the red positive terminal and the 1.5V negative terminal.

6. With the switch OPEN, determine how many paperclips your nail can lift (using magnetism)

7. With the switch CLOSED, determine how many paperclips you can lift with the nail.



Note that the figure shows the wire wrapped around the nail 4 times. Continue wrapping your wire so there are 20 turns in your coil.

4. Use the switch so we don't drain our batteries!

5. Connect your wires to the red positive terminal and the 1.5V negative terminal.

6. With the switch OPEN, determine how many paperclips your nail can lift (using magnetism)

7. With the switch CLOSED, determine how many paperclips you can lift with the nail.

Observations and Explorations

1. Based on what you saw in the above experiment, list things that you think could affect the strength of your electromagnet, and how they would affect the strength. (Use a separate sheet of paper if needed.)

2. Think of a way to reverse the polarity of your electromagnet. How could you measure the polarity of your electromagnet?

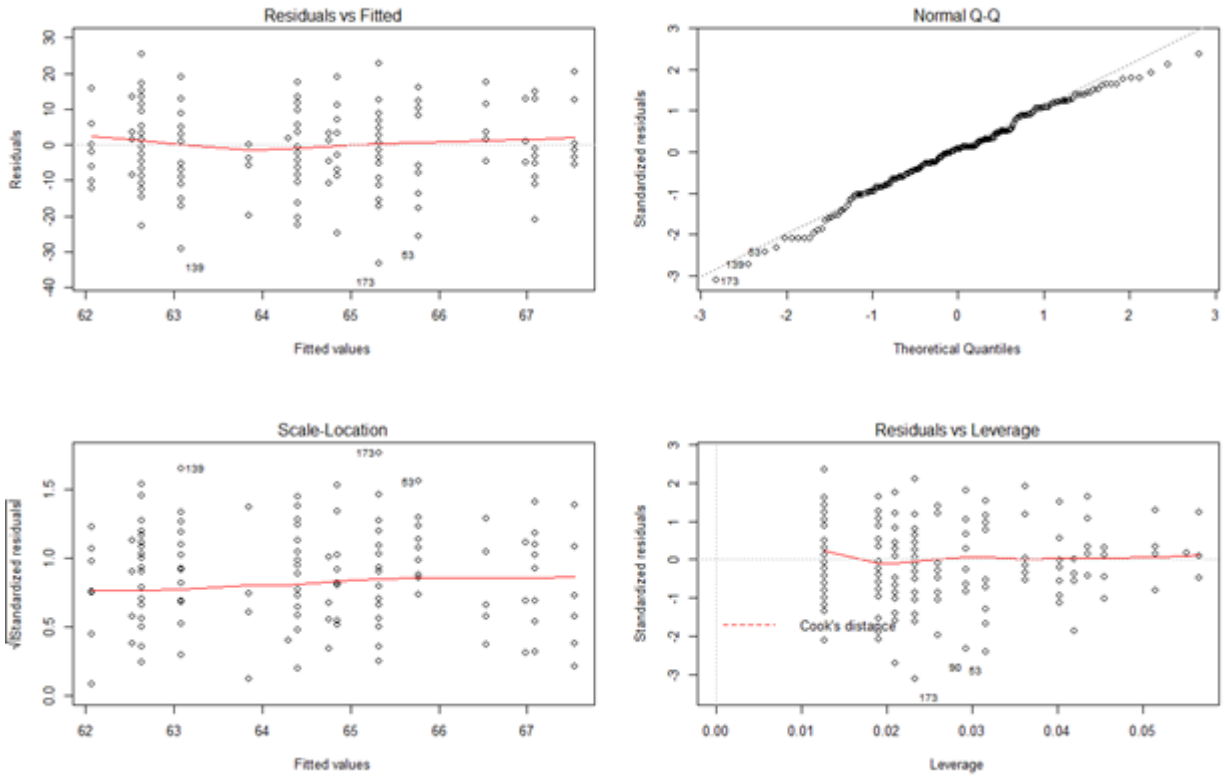
3. Attempt to implement your predictions above, one at a time, and record your observations.

You may use the number of paper clips that you can pick up as a measure of the electromagnet's strength. (Or you could try to determine how strong the paperclips bind to the nail by feel). If you have a magnetic field meter available, use that!

Further Thoughts

Using your recently gained knowledge of electromagnetism, describe how you think you could use an electromagnet to make an electric motor. That is, how can you use an electromagnet (and possibly other materials) to convert electrical energy into mechanical energy (motion)?

APPENDIX L: Selected Outputs for Inferential Statistics from SPSS/STATA



Learner code	Gender	LEARNING STYLE DIMENSIONS																		PRE-TEST SCORES	POST-TEST SCORES
		PROCESSING						PERCEPTION				INPUT				UNDERSTANDING					
		ACTIVE			REFLECTIVE			SENSORY			INTUITIVE			VISUAL			VERBAL			SEQUENTIAL			GLOBAL			%	%
		M	M	S	M	M	S	M	M	S	M	M	S	M	M	S	M	M	S	M	M	S	M	M	S		
LC1	Female	1							1					1							1					30	68
LC2	Female	1							1								1				1					12	50
LC3	Female	1						1						1									1			34	68
LC4	Female				1				1						1					1						18	42
LC5	Male	1							1						1								1			44	72
LC6	Female		1						1					1									1			40	52
LC7	Female					1			1					1						1						36	54
LC8	Female	1						1							1						1					58	78
LC9	Female	1						1										1			1					46	62
LC10	Female	1						1									1			1						12	64
LC11	Male					1					1			1							1					22	60
LC12	Female	1						1									1				1					48	66
LC13	Female	1						1						1										1		28	68
LC14	Female				1						1			1						1						50	64
LC15	Female	1						1							1							1				30	74
LC16	Female		1								1			1							1					32	68
LC17	Female	1						1						1										1		28	72
LC18	Female				1			1									1				1					36	62
LC19	Female					1					1							1			1					40	70
LC20	Female		1								1				1									1		48	66
LC21	Female					1		1											1				1			12	64
LC22	Female				1							1		1						1						32	64
LC23	Female	1										1		1									1			26	76
LC24	Male	1						1						1						1						20	66
LC25	Male	1						1						1									1			44	68
LC26	Female		1					1						1							1					20	60
LC27	Female	1							1						1					1						18	40
LC28	Female	1						1						1						1						28	68
LC29	Female	1									1			1						1						22	56
LC30	Male				1			1						1						1						22	70
LC31	Female				1			1						1						1						22	64
LC32	Male				1						1			1						1						24	60
LC33	Female	1						1						1						1						34	78
LC34	Female		1					1						1						1						24	68
LC35	Female	1						1						1						1						44	68
LC36	Female	1							1					1						1						30	48
LC37	Female		1						1									1		1						24	60
LC38	Male				1				1								1						1			34	62
LC39	Female				1				1					1						1						48	76
LC40	Male		1							1				1						1						36	56
LC41	Male	1							1								1							1		48	58
LC42	Female	1								1								1		1						28	66
LC43	Female				1				1					1							1					38	68
LC44	Female	1							1					1						1						26	60
LC45	Female		1						1								1			1						34	64
LC46	Female		1								1			1						1						38	60
LC47	Female			1				1									1						1			24	52
LC48	Female		1					1						1									1			44	52
LC49	Female		1					1							1								1			38	56
LC50	Female					1		1							1					1						30	54
LC51	Male		1					1									1			1						48	88
LC52	Female		1					1						1						1						22	64
LC53	Female		1					1										1					1			22	40
LC54	Male		1					1									1			1						42	74
School C																										1738	3408

School D											
LC55	Male	1		1		1		1		20	60
LC56	Male	1		1		1			1	18	56
LC57	Male		1		1	1		1		22	58
LC58	Male		1	1		1		1		36	82
LC59	Male	1		1		1		1		22	80
LC60	Female	1		1		1		1		36	68
LC61	Male		1	1			1	1		48	80
LC62	Female	1		1			1		1	30	74
LC63	Female		1	1		1		1		42	82
LC64	Male	1		1		1		1		36	40
LC65	Female		1	1		1		1		34	60
LC66	Female	1		1		1		1		24	62
LC67	Male	1		1		1		1		38	66
LC68	Female	1		1		1			1	48	82
LC69	Female	1		1			1	1		26	56
LC70	Female		1	1		1		1		28	48
LC71	Male		1	1		1		1		28	56
LC72	Female	1		1		1		1		28	56
LC73	Male		1		1		1		1	38	80
LC74	Female	1		1		1		1		46	76
LC75	Female	1		1		1		1		20	58
LC76	Female	1		1			1	1		44	78
LC77	Female	1		1		1		1		30	64
LC78	Female		1	1			1		1	28	66
LC79	Female		1	1			1	1		48	66
LC80	Male		1	1		1		1		40	74
LC81	Female	1		1		1		1		38	54
LC82	Male	1		1			1	1		38	68
LC83	Male	1		1		1		1		42	74
LC84	Female	1		1		1			1	26	66
LC85	Male		1	1		1		1		30	48
LC86	Male		1	1			1	1		24	56
LC87	Female		1	1		1		1		28	70
LC88	Female	1			1		1	1		32	66
LC89	Male	1		1		1			1	36	48
LC90	Male		1	1		1			1	30	40
LC91	Male		1	1		1		1		42	74
LC92	Female	1		1		1		1		28	60
										1252	2452

School A											
LC93	Female	1		1		1		1		28	76
LC94	Female	1		1		1			1	32	76
LC95	Female	1			1		1	1		22	54
LC96	Female	1		1		1		1		36	58
LC97	Female	1		1			1	1		32	72
LC98	Female	1			1		1	1		34	66
LC99	Male		1	1		1			1	28	62
LC100	Female		1	1		1		1		36	76
LC101	Female	1			1	1		1		30	50
LC102	Male		1	1			1	1		32	64
LC103	Male	1		1		1		1		34	64
LC104	Male	1		1			1		1	36	78
LC105	Female		1		1		1		1	34	62
LC106	Male	1		1		1		1		34	72
LC107	Male		1	1		1			1	34	84
LC108	Female		1	1			1		1	32	80
LC109	Female	1		1		1		1		34	68
LC110	Female	1		1			1	1		36	70
LC111	Female		1	1			1	1		28	64
LC112	Female	1		1		1		1		28	72
LC113	Female	1		1		1		1		38	66
LC114	Female	1		1		1		1		26	74
LC115	Male	1		1			1		1	20	82
LC116	Male		1	1			1	1		18	82
LC117	Female	1		1			1	1		34	54
LC118	Male	1		1			1	1		34	68
LC119	Female	1		1			1		1	32	60
LC120	Male	1		1		1		1		22	72
LC121	Female	1		1			1	1		28	64
LC122	Female		1	1			1	1		30	46
LC123	Female		1	1		1		1		38	64
LC124	Female	1			1	1		1		28	52
LC125	Male	1		1		1		1		36	64
LC126	Female	1		1		1			1	28	64
LC127	Female	1		1		1			1	36	46
LC128	Female		1	1			1	1		38	58
LC129	Male		1		1		1	1		32	78
LC130	Male		1	1		1			1	38	84
LC131	Female	1		1		1		1		36	50
LC132	Male	1			1		1	1		26	66
LC133	Female	1		1		1			1	32	56
LC134	Male		1	1		1			1	38	76
LC135	Female	1		1			1	1		22	68
LC136	Male	1			1	1		1		32	78
LC137	Female	1		1			1		1	26	76
LC138	Male		1	1		1			1	34	76
LC139	Male	1		1		1			1	22	34
LC140	Male		1	1			1	1		38	82
LC141	Male	1		1			1		1	20	48
LC142	Male	1		1		1		1		30	62
LC143	Male	1		1		1			1	34	58
LC144	Female		1	1		1		1		32	74
LC145	Male		1		1		1	1		34	84
LC146	Female		1	1		1		1		38	76
LC147	Female		1	1			1	1		30	58
LC148	Female	1		1		1		1		28	76
LC149	Female		1	1		1			1	38	62
LC150	Male		1	1		1		1		30	78

SCHOOL B										1816	3884
LC151	Male	1		1		1			1	24	66
LC152	Female	1		1		1		1		22	72
LC153	Female	1		1		1		1		28	64
LC154	Female	1		1		1		1		24	56
LC155	Female		1	1		1			1	42	68
LC156	Female		1		1		1	1		26	68
LC157	Male		1	1		1		1		16	42
LC158	Female		1		1	1			1	32	66
LC159	Male		1	1		1		1		28	42
LC160	Male	1		1		1		1		38	64
LC161	Male		1	1		1			1	22	58
LC162	Male	1			1	1			1	42	64
LC163	Male	1		1		1			1	38	56
LC164	Female	1		1		1		1		26	52
LC165	Female		1	1		1			1	24	72
LC166	Female	1			1	1			1	28	54
LC167	Female	1		1		1		1		22	64
LC168	Female	1		1			1		1	32	76
LC169	Female	1		1		1		1		38	66
LC170	Male	1		1		1			1	22	54
LC171	Female		1	1		1		1		30	56
LC172	Female		1	1		1		1		32	44
LC173	Male	1		1			1	1		28	32
LC174	Female		1		1	1		1		30	44
LC175	Female	1		1		1		1		26	64
LC176	Female		1	1			1		1	30	68
LC177	Female		1	1			1	1		26	64
LC178	Female		1	1			1	1		36	56
LC179	Female		1	1		1		1		38	62
LC180	Female		1	1			1	1		66	82
LC181	Female	1			1		1	1		28	68
LC182	Male	1		1		1			1	36	66
LC183	Male		1	1		1		1		34	60
LC184	Male	1		1		1		1		44	72
LC185	Male		1		1		1	1		30	62
LC186	Male	1		1		1			1	20	64
LC187	Male	1			1	1		1		32	62
LC188	Female	1		1		1		1		24	68
LC189	Female	1			1		1	1		28	60
LC190	Female	1		1		1			1	32	68
LC191	Female		1		1		1		1	36	68
LC192	Female		1	1		1		1		38	64
LC193	Male		1		1	1		1		28	64
LC194	Female	1		1		1		1		44	60
LC195	Female	1		1			1	1		34	48
LC196	Female		1	1		1			1	22	56
LC197	Female	1		1		1			1	38	54
LC198	Female	1		1		1		1		42	88
LC199	Male	1		1		1			1	38	64
LC200	Female		1	1		1		1		28	58
LC201	Female		1	1		1		1		22	64
LC202	Female	1		1		1		1		24	52
LC203	Female		1	1			1	1		46	82
LC204	Female	1		1		1		1		40	62
LC205	Male		1	1			1		1	42	88
										1746	3418

CONTROL GROUP (SCHOOL E)											
LCG1	Male		1		1		1		1	30	46
LCG2	Male	1		1			1		1	24	24
LCG3	Male		1	1		1		1		32	38
LCG4	Female		1		1	1			1	34	24
LCG5	Male	1		1			1		1	34	38
LCG6	Male	1		1		1			1	30	32
LCG7	Female	1			1		1	1		34	44
LCG8	Female	1		1		1		1		36	52
LCG9	Female	1		1			1	1		34	50
LCG10	Male	1		1			1		1	38	32
LCG11	Female		1		1	1			1	24	54
LCG12	Female		1	1			1	1		38	38
LCG13	Female	1		1		1			1	24	42
LCG14	Male		1		1	1		1		30	32
LCG15	Female	1			1	1		1		32	44
LCG16	Male		1		1		1	1		34	36
LCG17	Male	1		1		1			1	36	58
LCG18	Female		1	1			1	1		34	28
LCG19	Female		1		1		1	1		26	38
LCG20	Male	1			1	1			1	34	36
LCG21	Female		1	1			1		1	26	42
LCG22	Female		1		1		1	1		44	34
LCG23	Male	1		1		1			1	32	34
LCG24	Female	1		1		1		1		38	28
LCG25	Male	1		1		1			1	32	40
LCG26	Female	1		1		1		1		36	32
LCG27	Female		1	1		1		1		34	32
LCG28	Female	1		1		1		1		32	26
LCG29	Female	1			1	1		1		20	32
LCG30	Male		1	1		1		1		20	36
LCG31	Female		1		1	1		1		32	32
LCG32	Male	1		1		1		1		26	48
LCG33	Female	1		1		1		1		36	42
LCG34	Female		1	1		1		1		38	42
LCG35	Female	1			1	1		1		28	32
LCG36	Female		1	1		1		1		38	36
LCG37	Female		1		1		1		1	32	44
LCG38	Male		1		1	1		1		30	34
LCG39	Female	1			1		1		1	36	38
LCG40	Male	1		1		1		1		22	38

	Male	Female	p-value
	n(%)	n (%)	
Active processing	49 (56.32)	100 (63.29)	0.2849
Reflective processing	38 (43.68)	58 (36.71)	0.2849
Sensory perception	70 (80.46)	126 (79.75)	0.8938
Intuitive perception	17 (19.54)	32 (20.25)	0.8938
Visual input	61 (70.11)	105 (66.46)	0.5576
Verbal input	26 (29.89)	53 (33.54)	0.5576
Sequential understanding	51 (58.62)	118 (74.68)	0.0093*
Global understanding	36 (41.38)	40 (25.32)	0.0093*

Notes	The null hypothesis is that there is no difference between the proportion of a characteristic by gender	
	Example	Null hypothesis: Proportion of male students with active processing=proportion of females with active processing
		Alternative hypothesis: Proportion of male students with active processing ≠ proportion of female students with active processing
	All were not statisitically significant except sequential and global understanding	
	Statistically significant differences observed for sequential and global understanding.	

Is ANOVA suitable to test equivalence of scores in the experimental schools?

1. **Outliers: Using box plots (Figure 2)- some outliers are observed.**

2. **Testing for Normality: Shapiro wilk test**

School	Pretest Obs	Pretest p-value	Post test Obs	Post test p-value
School A	58	0.01270	58	0.09193
School B	55	0.00398	55	0.08491
School C	54	0.49805	54	0.33991
School D	38	0.90049	38	0.66386
Interpretation	*** Reject null hypothesis assuming normality for school B		*** No evidence to reject the null hypothesis assuming normality	

3. **Testing homogeneity: Levene's test**

Score	Experimental p-value	All Schools p-value
Pretest	<0.0001	<0.0001
Post test	0.2427	0.0726
Interpretation:	*** The homogeneity assumption was violated in Pre test scores for the experimental schools	

Overall Conclusion:

*****We do not use ANOVA to test for equality of means in the pretest scores for the experimental schools but we will use Kruskall-wallis test.**

***** To compare post test scores, ANOVA will be suitable.**

Comparison of Pretest scores in the experimental schools

school	Obs	Rank Sum
School A	58	5895.00
School B	55	5477.00
School C	54	5576.50
School D	38	4166.50
Chi square:	0.696	
df	3	
p-value	0.8742	
Conclusion:		

A Kruskal wallis test was conducted to determine if pre-test scores were different for 4 experimental group schools

The test showed that there was no statistically significant difference in the pretest scores of the 4 schools

Comparison of Pretest scores

school	Obs	Rank Sum
School A	58	7010.50
School B	55	6511.00
School C	54	6646.50
School D	38	4972.50
School E	40	4994.50
Chi square:	0.780	
df	4	
p-value	0.9410	
Conclusion:		

Comparison of Pre and Post test scores by school category

	t- statistic	Mean diffence	Standard Deviation	95% CI	df	p-value
Experimental	-41.0836	32.24	11.24	).69 -33.'	204	<0.0001
Control	-3.8931	5.95	9.67	.86 - 9.0	39	0.0004

ANOVA - Post test in all schools

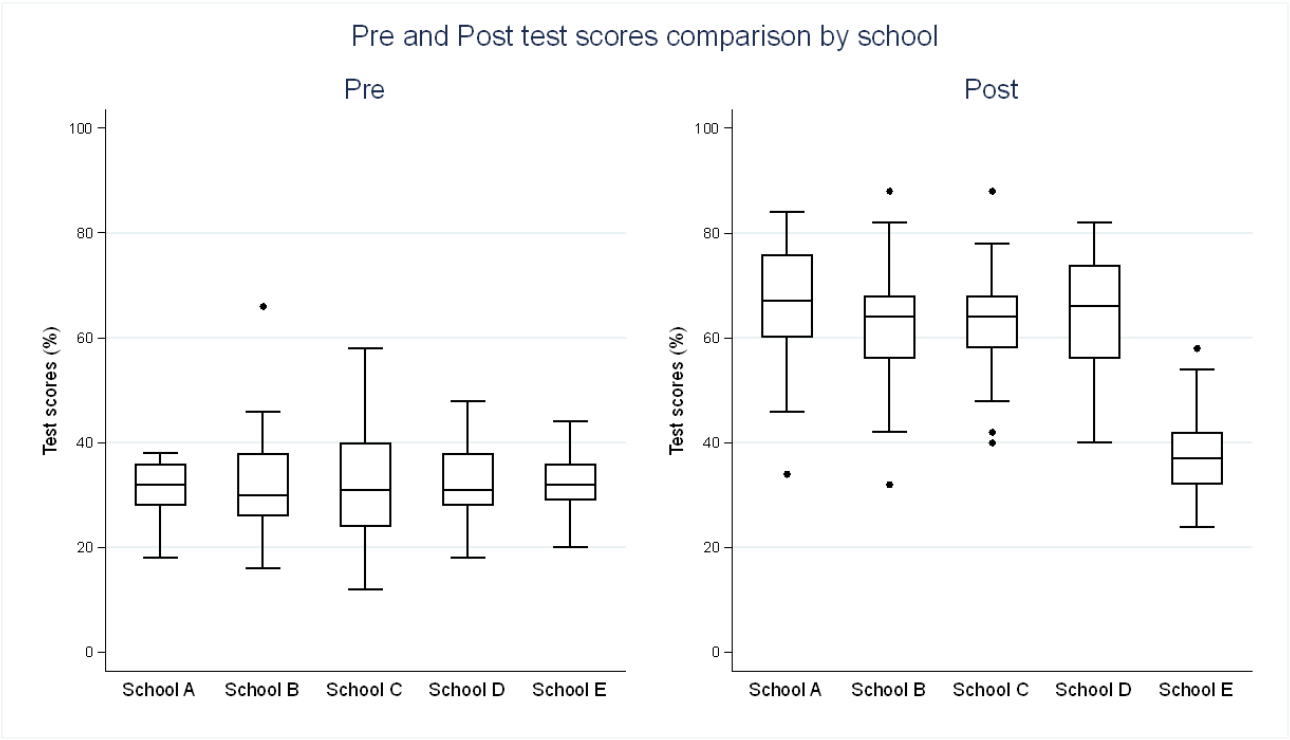
Source	SS	df	MS	F	p-value
Between groups	24256.3521	4	6064.08	56.80	<0.0001
Within groups	25623.9744	240	106.76656		
Total	49880.3265	244	204.427568		

Interpretation of results: The p-value is <0.001 , which is below 0.05, and, therefore, there is a statistically significant difference in the mean post test scores between the 5 schools.

ANCOVA- ANOVA of post tests while controling for pre test scores

Source	**Partial SS**	**df**	**MS**	**F**	**p-value**
Model	26905.753	5	5381.1505	55.98	<0.0001
school	24180.259	4	6045.0647	62.89	<0.0001
Pre	2649.4006	1	2649.4006	27.56	<0.0001
Residual	22974.574	239	96.127924		
Total	49880.327	244	204.42757		

Interpretation of results: The p-value is <0.001 , which is below



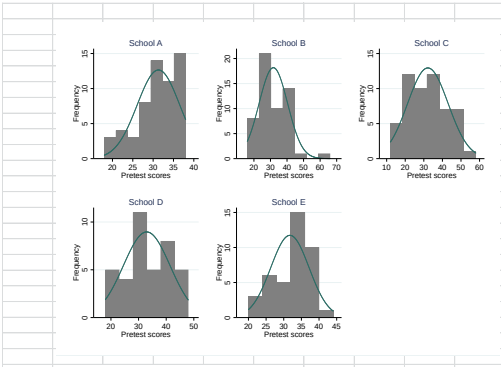


Figure1: Histograms of pretest scores by school

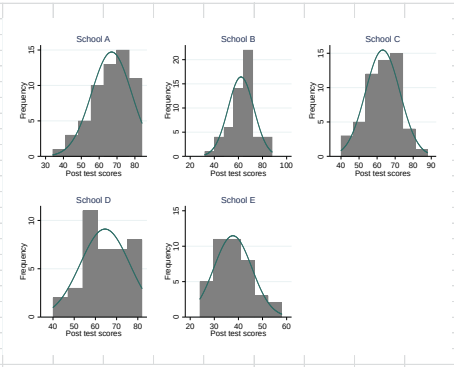


Figure2: Histograms of posttest scores by school

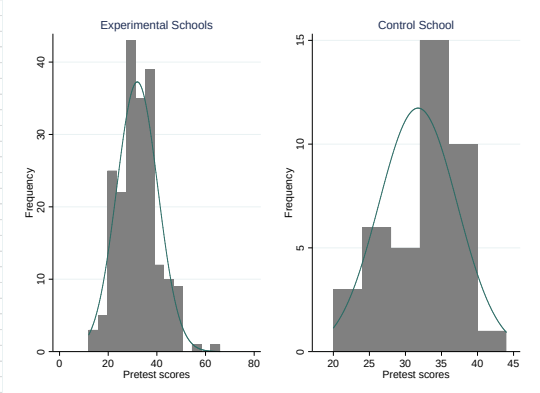


Figure 3: Histograms of Pre test scores by school category

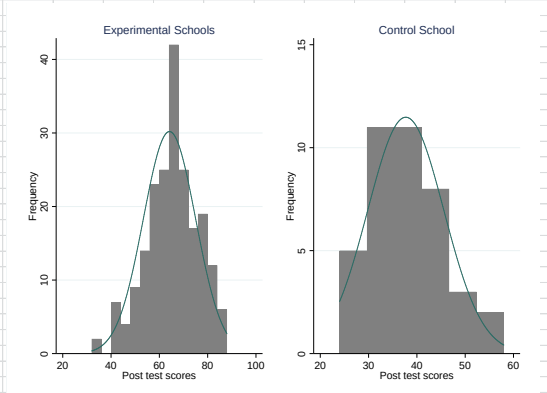


Figure 4: Histograms of Pre test scores by school category