Teaching Newton's Second Law of Motion in Grade 11 Physical Sciences using a Conceptual Change Approach

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DECLARATION

I declare that "*Teaching Newton's second law of motion in Grade 11 Physical Sciences using a Conceptual Change Approach"* is my own work and that all the sources that I have used or quoted have been acknowledged by complete references.

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Neliswa Tembani   Date:

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ABSTRACT

The purpose of this study was to investigate how the use of a conceptual change approach could contribute to enhance the teaching and learning of Newton's second law of motion in Grade 11 Physical Sciences. More specifically, the study attempted to answer the main research question namely, **How can teaching using a conceptual change approach improve the learners' achievement in Newton's laws of motion?** This study was underpinned by the theories of constructivism and conceptual change. The concept of effective teaching practice is based on approaches that promote conceptual change and provides learners with skills on learning how to learn and make meaning out of their learning - which is part of the constructivist view of learning.

The sample of this research consisted of a single class in a school where the researcher is teaching. The class has 33 learners of mixed gender. The study adopted a single case study approach and was designed to allow for the use of multiple data collection methods. Data was collected through a pre- and post-tests, intervention lessons as well as semi-structured focus group interviews. The use of qualitative and quantitative methods of data collection provided useful and in-depth data and allowed for triangulation. The data was analysed both quantitatively and qualitatively.

The results of the research showed that learners performed better in the post-test than in the pre-test. The learners mentioned the fact that the intervention lesson played an important role in making them understand the concepts better. The results also showed that, while the majority of the learners seemed to have made some progress in their conceptual development as a result of their exposure to conceptual change method of teaching, others struggled with the approach.

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CHAPTER 1

RATIONALE OF THE STUDY

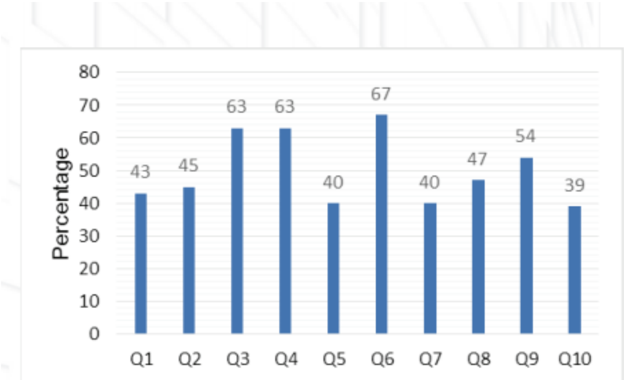
1.1 INTRODUCTION

In this introductory chapter, the background of the study, research problem, research question, significance, limitations and the structure of the study will be discussed.

1.2 BACKGROUND TO THE STUDY

The number of scientists and engineers produced by the country is an important indicator of a country's scientific and technological infrastructure as well as its ability to make a contribution to the scientific and technological world (Bubenzer, 2008). In other words, a large adequate and well-trained scientific workforce is pivotal to economic growth, social development and improved quality of life for all citizens. In a nutshell, science is an instrument for sustainable development (Cameron, 2009). Therefore, South Africa faces major challenges of improving and increasing the human resource in science by enhancing the academic performance of learners in science at matriculation level.

At national level the general performance of candidates in Physical Sciences reflects a decline from that of the past two years. In comparison to 2013, it was noted that the number of candidates who wrote the subject in 2014 has decreased. The number of candidates who passed at the 30% level declined by 5,9 percentage points and those who passed at the 40% level also declined by 5.8 percentage points. Candidates achieving distinctions over 80% increased marginally from 3.1% to 3.3% of total candidates (2014 - NSC Diagnostic report). It is evident from the report that most of the learners in Physical Sciences are struggling to get good symbols in this subject. This is a national challenge worthy of investigation. Hence, this research was done to find ways in which this problem could be solved.



Q1	Multiple choice questions
Q2	Newton's laws of motion
Q3	Vertical projectile motion
Q4	Momentum
Q5	Work, energy and power
Q6	Doppler effect
Q7	Electrostatics
Q8	Electric circuits
Q9	Motors, generators and alternating current
Q10	Photo-electric effect

Figure 1: average marks per question in P1 of Physical Sciences 2014

According to the 2014 NSC Diagnostic Report, mechanics is one of the topics in which learners perform poorly as represented in Figure 1 above. Specifically, the common errors and misconceptions of learners on Newton's laws of motion are:

- Learners fail to state Newton's second law of motion correctly; some candidates still wrote "force is directly proportional to acceleration and inversely proportional to mass".
- If more than one objects are given linked to one another by string to form a system, many candidates failed to identify all the forces and the direction in which they act on each object.
- The value of 9.8m. s^{-2} is usually incorrectly substituted for acceleration.
- Net force (F_{net}) was wrongly identified.
- Many candidates were unable to apply the direction convention.

Table 1: The results for the Eastern Cape and Mthatha district for Physical Sciences 2010-2014

	Eastern Cape Province	Mthatha
2010	43,3	51,3
2011	46	53,7
2012	50,4	56,2

Table 1 above shows clearly that physical sciences is really a challenging subject to the learners. Even though the results for the district are higher than the scores for the provincial average, the pass percentages are still in the fifty percent range. The

Eastern Cape Province usually performs poorly compared to other provinces in South Africa in terms of grade 12 results and physical sciences is one of the subjects with a low pass percentage. The learners usually perform better in paper 2 (chemistry) whereas paper 1 (physics) is a challenge for learners. In physics the knowledge area called 'mechanics' covers a bigger part and is dominated by Newton's laws of motion. Therefore, the researcher feels that if learners' understanding of Newton's laws of motion is improved using, for example, a conceptual change approach, the results in this area could improve. With the researcher's experience and observations, she found that one of the reasons for the low pass rate could be that learners interpret concepts in their own way, which is not always scientifically correct. If this is the case, then conceptual change theory and model could work to improve the low pass rate. Tutoring, whether working with smaller groups or individual teaching and support, can change the learners' understanding of Newton's laws of motion to increase learner performance.

1.3 STATE OF SCIENCE EDUCATION IN SOUTH AFRICA

Mathematics and science performance remain vital to job creation, economic growth and prosperity. For this reason, the action plan for 2014 (Diagnostic Report, 2014) underpins the improvement of mathematics and physical sciences as one of its primary goals. In addressing this goal, the Department of Basic Education (DBE) will continue to promote excellence in both mathematics and science education.

The release of the World Economic Forum's (WEF) *Global Information Technology Report 2014: Rewards and Risks of Big Data* in June 2014 received varied responses in South Africa. The Report's central focus is, as it states, global information technology - and the readiness of countries to avoid the risks, and benefit from the very considerable rewards associated with 'big data'. As part of the analysis presented in the Report, the general quality of education systems, and of mathematics and science education in particular, are scored - a small part of the overall assessment, but (of course) telling in itself. The Report placed the general status of South Africa's education system at 146 out of 148 countries, and the mathematics and science education at 148 out of 148. By comparison, Swaziland was placed at 81 and 91, respectively, and Zambia at 38 and 76.

The Minister of Science and Technology, Naledi Pandor, is quoted as saying that the Report's findings were 'based mainly on perceptions, rather than testing of the learners'[1], while the Department of Basic Education (DBE, 2014) issued a media release stating[2]:

> The Report is not a credible or accurate reflection of the state of education in South Africa. This Report falsely insinuates that South Africa's mathematics and science education is ranked as the worst in the world. The DBE rejects this finding as it is based purely on the opinions or perceptions of selected executives (page 12).

Adrian Schofield, a Fellow and Professional Member of the Institute of Information and Technology Professionals of South Africa, has offered a more nuanced view:

> The DBE is right about the Report being based on the opinions of selected executives, and only a handful of them. Without some rigorous investigation of how they are selected and what sort of sample cross-section they represent, it is impossible to gauge how much reliance to place on their responses. Even if we are satisfied with the sample, they still only represent business interests, and it would be better to include other stakeholders in the sample, together with a data-based analysis of pass marks and pass rates (National Diagnostic Report for NSC Results 2014, p 120).

Schofield does not agree, however, that the findings are 'grossly inaccurate'. He suggests that many people agree that the average quality of education in South Africa is abysmal. 'If we can achieve the halfway point in the Network Readiness Index, we should be able to achieve at least that in education' (p 119).

A very serious problem experienced in South Africa is that there are not enough learners leaving the school system with good mathematics and physical sciences results. This has caused skills shortages in the economy, particularly in areas like medicine and financial management. Presently around one in seven young people leave school with a grade 12 pass in mathematics. The number is even lower for physical sciences. The aim is to increase this around one in five by 2014 and one in three by 2025 for each subject. To this effect, Government has for a number of years been paying special attention to improving mathematics and physical sciences results in grades 10 to 12. A greater number of science graduates results in a more skilled and therefore a more productive work force, which in turn contributes to an internationally more competitive nation and to redressing the balance of trade problems (Robottom & Hart, 1993). This belief is reiterated frequently, for example in the South African White Paper on science and technology (DST, 1996), which states that “science is considered to be among the requirements for creating wealth, and improving the quality of life” (p 10).

Realising the importance of science to development, Africa has, according to Ogunniyi (1996), been eager to develop its scientific human power to attain a measure of self-reliance in the production of goods and services by expanding its educational facilities and setting up curriculum development and research centres, as well as developing policies on science education. In South Africa (SA) similar developments in science and science education are exemplified by, for example:

- The creation of a Ministry of Science, Technology and Culture, which declared 1998 and 2000 Years of Science and Technology;
- Prioritising research in science, for example by the National Research Foundation (NRF);
- Increasing the focus towards science by universities of Venda, the North, of Cape Town, and of Fort Hare;
- Further Diploma in Education in science education (FDE), now the Advanced Certificate of Education (ACE), for retraining science teachers;
- The Department of Education (DoE) commissions to improve science education;
- Scholarships for science teachers from, for example, ESKOM;
- Manufacturing of science teaching equipment by, for example, the Somerset Educational institution;
- Media interventions such as the SABC Education and Liberty Life programmes on science;

- Creation of NGOs such as CASME and All Saints specifically for science education, and an increase in the awareness of traditional science;
- Outreach programmes such as by ZENEX and ABSA, equipping schools with Somerset micro science kits;
- Science centres, such as the Interactive Science Centre at Cape Town;
- Research conferences on science education such as the South African Association for Research in Science and Mathematics Education (SAARMSE);
- Programmes for upgrading science educators such as that by the North West DoE (EDUSOURCE DATA NEWS, March 2000: 25) and;
- The SYSTEM initiative by the DoE aimed at increasing scientists.

Such efforts have provided SA with World-class scientists and contributed towards science education. However, beyond the passionate rhetoric and such interesting interventions, science education appears to be experiencing problems that could lead to a crisis. In Africa, the Dakar Declaration indicates large socio-economical obstacles against efforts towards human power development in the field of science and a poor state of science education (Ogunniyi, 1996). In SA these obstacles are widely articulated, for example by MacDonald & Rogan (1988:234), who found in the Eastern Cape Province impoverished communities that could not contribute towards curriculum development, poor school resources and inadequate teacher training. The low pass rates in science at Matric level (South African Broadcasting Corporation, PM Live programme, 10th January 2000) and occasional reports on the low international ranking of science education were believed to be among the indicators of problems in science education in SA. The researcher has experienced or found similar problems in the Eastern Cape.

Teachers often claim that lack of science equipment and laboratories prevent them from teaching science practically. However, there is evidence that teachers who have equipment do not use it. It appears therefore that, apart from work overloads, the main reason why teachers do not use practical approaches is that they are deficient in practical skills and do not understand the science concepts they are supposed to teach. This claim is demonstrated in schools that have science equipment.

1.4 INTERVENTIONS IN SCIENCE EDUCATION IN SA AND THE EASTERN CAPE

It also appears that deficiency in understanding specific subject content areas is a problem in many schools. The problem appears to be compounded by a shallow grasp of some of these content areas by teachers, or by teachers neglecting to cover certain aspects of the curriculum. The poor quality of responses even in lower order questions suggests that some of the candidates were not adequately exposed to the relevant content. Meaningful and effective interventions at the teacher level consequently remain a major priority. Evidence also points to a cumulative deficit of subject content on the part of learners.

An important programme of Government is Dinaledi, which started in 2001. In 2007 this programme was expanded so that it covered almost 500 schools in South Africa from the nine provinces. Recent evaluations by experts have found that the additional training and resources going to Dinaledi schools did make a difference to grade 12 results, especially in poorer areas. The challenge is to improve the Dinaledi approach further and to include more schools.

In the Eastern Cape Province there are programmes like enrolling educators in various institutions so as to advance their knowledge of the subject. As of now there is one such project offered by the Nelson Mandela Metropolitan University. It deals with mathematics and physical sciences educators. Then there is another one which is run by the University of the Western Cape. This programme is focused only on physical sciences educators and the emphasis is on content, experiments and projects. The educators are also shown how to present their lessons using power-point presentations so as to save time and cover more work within a short period of time. This type of presentation is more appealing to learners since it is technologically advanced and they tend to be more attentive, thereby grasping the subject matter more effectively.

1.5 CONTEXT OF THE RESEARCH

The school where I teach is situated in a community where the illiteracy level is very high. The learners are co-operative when it comes to school attendance. For example, when there are extra classes in the afternoons, weekends and holidays the learners do attend those classes. When the learners are promoted in the internal classes (in grades 10 and 11) the requirements are in such a way that if the learner has got only one level 1 out of seven subjects then the learner will be promoted to the next grade. The learners who are promoted to grade 12 usually meet the promotion requirements but have not achieved physical sciences. As a result, the quality of the results in physical sciences is poor. Most of the learners pass with 30% and very few learners manage to get 50% and above.

Table 2: The results of the sample school for the past three years

year	Total wrote	Number pass	Number fail
2014	38	9	29
2013	25	14	11
2012	13	9	4

In the sample school there is only one educator who is qualified to teach physical sciences. In each grade there is one class doing physical sciences. In grade 10 there are 70 learners doing physical sciences with 33 learners in grade 11 and 28 in grade 12.

1.6 RESEARCH PROBLEM

Science can be considered a body of evidence that emphasises the integration of scientific inquiry and knowledge (Staver, 2007:6). Science education prepares learners to study science at a higher level, follow a career in science and become scientific literate citizens. Research in science education plays an essential role in analysing the actual state of scientific literacy and the practice in schools in addition to the improvement of instructional practice and teacher education (Duit, 2007).

When one looks at the recent history of physical sciences grade 12 results for the past six years during the National Senior Certificate (NSC) examinations in South Africa, the results are not very encouraging (Department of Education, 2014). The statistics for physical Sciences accentuate the need for improved physical Sciences education by researching learners' conceptual knowledge in South Africa's multi-cultural environment.

Based on my experience as an educator, learners are struggling to get good results in physical sciences. There is a history of learners struggling with the knowledge area called Mechanics. This forms the greater part of paper 1, the physics paper in the National Senior Certificate examination. In order to improve the results of learners, it would be useful to investigate alternative methods of teaching this topic. It is for this reason that the conceptual change theory was selected as a teaching approach. In this study the conceptual change approach will be investigated to consider its effect as a teaching strategy to improve learners' understanding of Newton's second law of motion.

1.7 RESEARCH QUESTION

In order to respond to the research problem described above, this study will address the following research question:

How can teaching using a conceptual change approach improve the learners' achievement in Newton's laws of motion?

The following research sub-questions were investigated:

(i) What was learners' initial understanding of Newton's second law of motion?

(ii) How was the conceptual change approach implemented to teach Newton's second law of motion?

(iii) What was the learners' understanding of Newton's second law of motion after the conceptual change lessons?

(iv) What was learners' perception of the conceptual change approach as a teaching strategy?

1.8 SIGNIFICANCE OF THE STUDY

The results of this research could be beneficial to the learners, the school and the community at large if the learners' achievement in mechanics improves, thereby increasing the number of learners in the scientist pipeline in the South Africa. The study could provide insight into the application of the conceptual change approach to improve results in other challenging areas of the curriculum. The study provides baseline data with respect to the use of conceptual change theory in teaching physical sciences.

1.9 LIMITATIONS OF THE STUDY

The study is based on one school only; therefore, the results will not be provided on a broader basis. The sample used was only 33 grade 11 learners and was not representative of a bigger population of science learners. The learners used in the research did not have the same background on the topic being researched. The language is also a problem as the medium of instruction used in the research is not a mother tongue to the learners.

1.10 STRUCTURE OF THE THESIS

The thesis is outlined according to the following structure:

Chapter 1 Rationale for the Study

The justification for doing the study is explained in detail.

Chapter 2 Literature Review

The theories underpinning the conceptual change theory are discussed. The study is supported by the current studies dealing with teaching Newton's laws of motion using the conceptual change approach as a teaching strategy.

Chapter 3 Research Methodology

The research design and methodology, including the quantitative and qualitative research methods, are discussed. The procedures, design, population, sample and instrumentation that were used to measure the effectiveness of the conceptual change approach as a teaching strategies are discussed

Chapter 4 Research Findings

Findings from pre- and post-tests, the intervention and interviews are recorded.

Chapter 5: Discussion

The analysis, interpretation and synthesis of quantitative and qualitative data take place. Based on the learning gained, the effectiveness of the conceptual development teaching strategies is evaluated.

Chapter 6 Conclusions and Recommendation

A summary is provided and conclusions drawn regarding the effectiveness of the conceptual change approach to teach Newton's second law of motion.

1.11 CONCLUSION

In this chapter the rationale of the study was provided justifying the need for conducting the research. In the next chapter literature review is dealt with including theoretical framework and current studies related to the research.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter presents the theoretical framework of the study. It also shows the path of previous studies and how this investigation is linked to them. While it is giving the opportunity to learn from previous efforts, it also stimulates in identifying the gaps in the field. A good review, according to Boote and Beile (2005), is one which helps the researcher to learn from other scholars and stimulate new ideas. It also identifies gaps and suggests hypotheses so that new knowledge can be produced.

2.2 THEORETICAL FRAMEWORK

This study is underpinned by the theories of constructivism and conceptual change.

2.2.1 CONSTRUCTIVISM

Constructivism, according to Asan (2007), has an important influence in the science classroom. Robottom (2004) argues that learners use their own beliefs, interpretations and ideas to interpret information conveyed by teachers. Learning is seen by Robottom (2004) as conceptual change, constructing and reconstructing concepts, which includes existing concepts. Constructivism is therefore a major theory when working with conceptual change.

Students' current understandings provide the immediate context for interpreting any new learning. Regardless of the nature or sophistication of a learner's existing schema, each person's existing knowledge structure will have a powerful influence on what is learned and whether and how conceptual change occurs.

For the learner to construct meaning, he must actively strive to make sense of new experiences and in so doing must relate it to what is already known or believed about a topic. Students develop knowledge through an active construction process, not through the passive reception of information (Brophy, 1992). In other words, learners must build their own understanding. How information is presented and how learners are supported in the process of constructing knowledge is of major significance. The pre-existing knowledge that learners bring to each learning task is emphasised too.

The new curriculum of physics courses at secondary schools has been redesigned with a constructivist approach. The most significant requirements of the constructivist approach are that the teacher should guide rather than teach. He brings out students' old knowledge, corrects the misconceptions if there are any, makes up for missing information, and finally enables them to participate in class actively. In addition, he gives examples to students from daily life so that they can associate their old knowledge with the new one. He encourages his students to adopt scientific methods. Constructivism, which is closely associated with the conceptual change approach, comprises many strategies that teachers can use to spot their students' misconceptions and correct them.

Constructivism asserts that learners' cognitive structures actively build or construct new knowledge based on what they already know or can do by interacting with their environment in an attempt to make sense of the world (Berk, 2006; Donald et al., 2006; Shaffer & Kipp 2007). This implies that learners do not learn things in isolation from what they are already familiar. According to Piaget (in Kramer, 2002:7; Shaffer & Kipp 2007:250-251) each individual is born with some sort of collection of knowledge, skills, and values called 'schema'. For Piaget (in Shaffer & Kipp, 2007:251), cognitive development is development of schema or structures which are the means by which a person interprets and organizes experience.

In constructivist model, it is therefore believed that when a learner learns something new he builds or constructs it on top of what he already knows to fit the new learning and the old learning in a balanced way (Shaffer & Kipp, 2007:250; Sternberg, 2003:449; Morrison, 2009:116). Hence, from the constructivist's point of view, learning may be best described as an active process in which children and adults construct their own personal meaning of the objects and events through interactions with them by incorporating new information into prior knowledge, experiences, episodes and images (Shaffer & Kipp, 2007:249; Morrison, 2009:114; Trowbridge et al., 2004:23).

In other words, for meaningful learning to take place an individual's information should be related to the past, present and future experiences.

It may therefore be possible to conclude that acquiring knowledge involves personal construction of meaning and many informal theories that an individual develops about the natural phenomena (Sternberg, 2003:446; Donald et al., 2006:53). Furthermore, it may be presumed that knowledge is a result of constructive activity and exists in the mind of the cognising being where it is constructed or built and cannot be transferred to a passive receiver (Shaffer & Kipp, 2007:250; Morrison, 2009:113).

Piaget's (Posner, Strike, Hewson, & Gertzog, 1982) research on how learners interpret and experience phenomena had an extraordinary impact on modern-day learning theory. Learners use their senses to help them construct meaning and understanding. This is how they understand the world (Saunders, 1992). The learner creates these structures, beliefs or understandings in his/her mind to interact with the world. In short, Saunders (1992) explains it as the necessary subjective knowledge of the world. Robottom (2004) defines knowledge as concepts that are constructed in the mind of the learner; therefore, this study used concept maps to put these constructions on paper for observation.

Constructivism has an important influence in the science classroom where learners use their own beliefs, interpretations and ideas to interpret information conveyed by the teachers (Robottom, 2004; Asan, 2007). Each learner has to construct his own knowledge. This view is therefore more an individual construction process, thus highlighting the theory of constructivism.

Posner et al. (1982) state that we need to focus more on the learner's content (where did the alternative idea come from and why did it form?) rather than looking at the logical structure. From Wing-Mui's (2002) perspective, science learning is viewed from a constructivist perspective, which involves epistemological and conceptual development. In other words, when constructivism interacts with science learning, it involves epistemological and conceptual development. Ishii (2003) defines constructivism as the way people understand the world and construct their own frameworks. Constructivism is classified as a theory of knowing, rather than a theory of knowledge. In this view constructivism is described as a lens one can look through to make sense of the world. This is constructed in the individual's mind together with reality, meaning, knowledge and learning.

Learning is a rational activity (Posner et al., 1982), where learners experience and observe concepts and accept them as intelligible and rational. The rational meaning of learning focuses on what learning is, and not on what it is dependent. Learning (Wing-Mui, 2002), through a constructivist's view, is seen as a dynamic social process where learners construct knowledge, meaning or concepts from their observations or experiences in conjunction with their existing experiences. This is all done inside the learner's social setting. Constructivism allows the learner to become a more active member of learning and teaching, because when the learner arrives at the science classroom he/she already has his/her own understanding of how the world works and how certain natural events occur. In the framework of constructivism, the learner does not only receive knowledge from the teacher, but also uses "out of the classroom" knowledge. The teacher should discard the idea that a teacher is only there to manage the classroom and to supply knowledge.

The following are the most important aspects, according to Julie et al. (1993) of a constructivist approach:

- assists learners when working with new methods in the learning process;
- helps learners to expand their knowledge of the subject or topic; and
- helps learners to develop instructional methods to promote meaningful learning and scientifically acceptable concepts – to create a sense of enthusiasm to learn and to be active within their own learning.

These aspects can also be applied to the role of the teacher. When we use constructivism in mathematical or scientific situations, we say that there are only true facts, principles, theorems and laws, as described by Ishii (2003). This is how knowledge is perceived in science. To clarify this statement, we can use Newton's second law of motion as an example – "When a net force is applied on an object, it produces acceleration in the direction of the force applied. The acceleration is directly proportional to the force and inversely proportional to the mass of the object." – There is only one way this law is defined and that is the correct way.

Of constructivism Saunders (1992:136) states the following: "Meaning is constructed by the cognitive apparatus of the learner." The meaning of information or knowledge can only be created and formed by the learner in the learner's mind. The teacher can only convey the information, but the learner is the one that has to make sense of it. Wing-Mui (2002) states that when emphasis is placed on a constructivist instruction process, it increases certain areas in a science classroom. These areas include the learner's conceptual knowledge, active engagement with scientific content, and applying knowledge gained to real-world situations.

When learners (Bergquist & Heikkinen, 1990) want to understand new material, they must use the new knowledge and combine it with their existing knowledge. The main function of constructivism is to organise knowledge by using previous experiences or understandings. Past experiences formed from observing certain processes in the world are important for learners (Saunders, 1992) because they supply the learner with the ability to make predictions and to supply reasons for these predictions. These predictions don't always seem generally acceptable to the community or to scientists. But for the learner they make sense because they have been rationalised by past experiences. When a prediction is made and the learner's past experiences provide an incorrect prediction, the learner must be placed in a situation where he or she must compare the cognitive universe with the natural universe. In other words, the learner must be placed in a cognitive conflict.

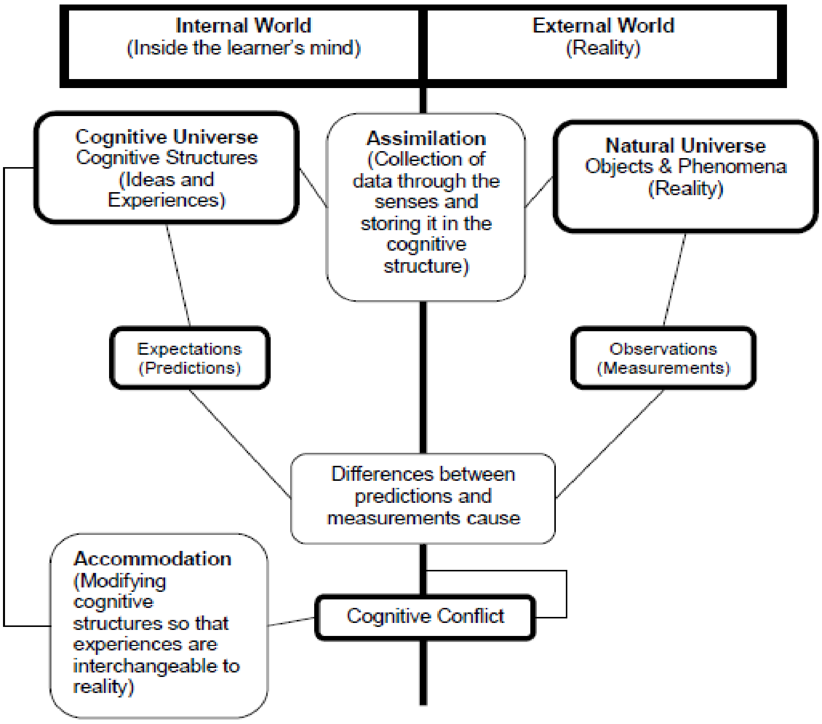


Figure 2: Adapted constructivism learning model

2.2.1(i) TYPES OF CONSTRUCTIVISM

There is a range of different constructivism types (Julie, Angelis, & Davis, 1993), and it is very important to choose the correct type to apply to specific situations. The reason for this is that a wide gap exists between the different types. To help choose the correct type of constructivism, one should consider or look for the underlying metaphors for the mind and world. The three types of constructivism are social, radical and information processing constructivism. It will be argued that social constructivism, as one of the types of constructivism, is more suited to this study because of its focus on learning as a social process.

a) SOCIAL CONSTRUCTIVISM

In this section an argument is advanced to contend why social constructivism is more appropriate for this study. Social constructivism (Julie et al*.*, 1993) is one of the newer types of constructivism. We can go as far as to say that it is not a form of constructivism, but a form of social-constructivism. In this type the real world is interconnected with the social world.

Kim (2001), Robottom (2004) and Treagust & Duit (2008) support this contention by stating that the focus of social constructivism is mainly on culture and context within society and that knowledge is constructed using the understanding gained through society. The underlying metaphor here is 'perceived as conversation', where the individual uses language to form meaningful structures. Social constructivism is based on certain assumptions (reality, knowledge and learning) and we need to understand these assumptions in order to apply a good instructional model, as researched by Kim (2001). Here reality is constructed through social activity, but reality does not exist prior to social invention (reality can therefore not be discovered).

Knowledge is also constructed within the social context where individuals create a sense of meaning by interacting with one another. Learning is viewed as a social process and meaningful learning occurs when individuals are busy with social activities. Julie et al*.* (1993) state that the model created in this type is a socially constructed one that shares the physical and social world's experiences. This is supported by Kundi and Nawaz (2010), who note that social constructivism is a collective learning process that receives information from the community, peers and parents.

The socially constructed model is modified constantly to adapt to the reality of real-world situations. In social constructivism there are two aspects that affect learning (Kim, 2001). One of the aspects comprises the symbol (language and logic) and mathematical systems that the learner obtains throughout his life; and the second aspect is the nature of interaction in society. Not everyone knows everything; therefore, we need to interact socially with other knowledgeable people. From them we acquire the knowledge to use the system efficiently to promote meaningful learning.

Learners arrive at the science class with their own ideas, beliefs and understanding of how things work (Robottom, 2004). Therefore, learning does not take place when the teacher fills the learner's head with information and data, but when we change or work with his/her existing ideas and beliefs. Learning is seen by Robottom (2004) as conceptual change, constructing and reconstructing concepts; this includes existing concepts. Constructivism is therefore a major theory when working with conceptual change and constructivism, for example, radical and/or social, influences the way research is conducted on conceptual change (Treagust & Duit, 2008).

b) RADICAL CONSTRUCTIVISM

Julie et al. (1993:168) describe radical constructivism as follows: radical constructivism is based on both the principles mentioned in information-processing constructivism and they elaborate: "The function of cognition is adaption and serves the organization of the experimental world, not the discovery of ontological reality." Ishii (2003) explains the terms "weak constructivism" or "radical constructivism", which differ from the definitions of Julie et al. (1993). Weak constructivism is described as the individual constructing his/her own knowledge and accepting the existence of objective knowledge, whereas radical constructivism is described as the individual's knowledge being in a continuous state of re-evaluation. We can therefore say that the individual's knowledge is continuously being adapted and evolved. To summarise this constructivism, we see it as the ability to use cognitive structure to adapt to the situation and ultimately to survive.

c) INFORMATION-PROCESSING CONSTRUCTIVISM

Raskin (2002) describes information-processing constructivism in the following way. This type of constructivism is defined as knowledge which is not passively received but actively built up by the cognising subject; and the rejection of an epistemologically sceptical principle. This combination forms a very weak form of constructivism.

Table 3: The three types of constructivism

Type of constructivism	**Mind metaphor**	**World metaphor**	**Applied to this study**
Information-processing constructivism	Computer-processing information.	Absolute space with physical objects.	Placing obtained information in a framework.
Radical constructivism	Adapting to situations.	Private domain of experiences.	Applying obtained data to a situation and changing it if the situation changes.
Social constructivism	Conversations.	Socially constructed, shared world.	Concepts gathered from teachers and/or experiences.

The metaphor of mind perceives the mind as a computer, processing the data. The metaphor of the world sees it as an “absolute physical space populated by objects”. The world is seen as unproblematic and knowable. Information-processing constructivism acknowledges that the learner is busy with active processes, both individual and personal, and that everything is based on the learner’s previous knowledge. Table 3 refers to the three types of constructivism and how they are applied within the context of this study.

2.2.2 CONCEPTUAL CHANGE THEORY

The process of learning in a conceptual change model depends on the extent of the integration of the individual's conceptions with new information. If he or she knows little about the topic under study, new information is likely to be combined easily with his or her existing ideas; the process that accounts for this event is what Posner et al. (1982) refer to as assimilation. On the other hand, the individual may have well-developed concepts about the topic under study. Often, these concepts may conflict and be contrary to what is understood as true by experts in that domain; such individual ideas are often referred to as alternative frameworks, and studies have shown these to be highly resistant to change (Champagne, Gunstone, & Klopfer, 1985; Nussbaum & Novick, 1982; Osborne & Freyberg, 1985). Overcoming these frameworks requires a more radical transformation of individual conceptions. This process is what Posner et al. (1982) refer to as accommodation. The processes of assimilation and accommodation are guided by the principle of equilibration whereby individuals seek a relatively stable homeostasis between internal conceptions and new information in the environment (cf. Chapman, 1988; Piaget, 1985).

This contrast between assimilation and accommodation presents another face of the paradox described above. That is, learners with relatively little prior conception of content to be learned have few barriers to learning new content. However, the literature is replete with studies showing the beneficial effect of prior knowledge on new learning. This body of literature also demonstrates that content learned in a disconnected fashion - that is, unintegrated with prior knowledge - is less meaningful and useful (Anderson, 1990). Thus, it is clear that prior knowledge can be useful in learning new content. However, prior knowledge can be organised in such a way that the concepts connecting this knowledge compete with concepts understood by a discourse community (e.g., a scientific field). Given that the scientific discourse community can influence the school curriculum (e.g., in terms of what is taught, how it is organised, what is in the textbook and curriculum materials, etc.), in such a situation students' prior conceptions can serve to resist the development of the more veridical conceptions that are represented in the curriculum.

Clearly, the process of accommodation is critical for the continuing educational development of learners. Without the process of accommodation working on prior conceptions of content, little conceptual growth would occur. Not surprisingly, then, most work on conceptual change has focused on what processes encourage or drive accommodation. To explain how current conceptions influence how an individual will view new information, Posner et al. (1982) use the metaphor of a conceptual ecology. Several assertions are implied by this metaphor. One is the systemic assumption that concepts exist in interrelated networks and that a change in one concept will affect how other concepts are viewed. Conceptual change in one area often leads to anomalies in the individual's conceptual ecology. This system view of learning suggests that considerable forces can be present that can have important consequences for whether conceptual change occurs or not. A second assertion is that individuals hold certain commitments and beliefs about the nature of knowledge. These epistemological beliefs are used by an individual as bases for determining what can or cannot be true or what is or is not a valid explanation of a problem raised in the effort to incorporate new experiences and information into that individual's conceptual ecology.

Finally, there is the possibility of ideas competing for the same conceptual niche; this is particularly important for accommodation. In such cases, the idea that wins out will most likely be the one that successfully resolves anomalies and conforms to the individual's beliefs about the nature of knowledge and truth - a survival-of-the-fittest ideas and concepts. The metaphor begins to exhaust itself at this point. Ecosystems are not purposeful, but individual learners and communities of scholars can and do have goals, purposes, and intentions, thereby suggesting a role for an individual's motivational beliefs. It is not clear how competing ideas in a purposeful ecosystem of the mind might behave differently from organisms and populations in a biological ecosystem.

In conjunction with the idea of a conceptual ecology, the conceptual change model states four conditions that must be fulfilled for accommodation to occur. These conditions are borrowed from an analysis of change in scientific paradigms, but they have been applied to individual learning by conceptual change theorists (Posner et al., 1982). The first condition is that of *dissatisfaction* with current conceptions. This suggests that, the less dissatisfied an individual is with his or her current understandings and ideas, the less likely he or she will be to consider a radical change of view. The second condition is that a new conception be *intelligible.* In order for an individual to consider a new concept as a better means of explaining experience than his or her current conception, he or she must be able to understand it. The third condition is that the new concept be *plausible.* While the learner might be able to understand the new concept, he or she may not see how it can be applied or may deem the new concept too inconsistent with other understandings to merit further consideration. Finally, the new concept must appear *fruitful;* that is, it must have explanatory power and/or suggest new areas for investigation. In this study the four conditions were explicitly used in lesson preparation of Newton's Second Law of Motion to facilitate a process of conceptual change.

This description of the four conditions necessary for conceptual change provides an interesting model of how learners might come to change their beliefs about academic subject matter. It presumes a very rational process of cognitive change, paralleling Brown, Bransford, Ferrara, and Campione's (1983:78) assertion that academic learning is "cold and isolated" cognition. That is, it suggests that learners behave very much like scientists in that, when they become dissatisfied with an idea, they will then search out new intelligible, plausible, and fruitful constructs that will balance their general conceptual model. However, there are both theoretical and empirical reasons to believe that academic learning is not cold and isolated. For example, there is empirical evidence that more affectively charged motivational beliefs, such as students' self-efficacy beliefs, and their goals for learning, can influence their cognitive engagement in an academic task (see Pintrich & Schrauben's review, 1992).

Accordingly, individual students' motivational beliefs may influence the process of conceptual change. In addition, there is a great deal of theoretical and empirical research to suggest that individual learning in classrooms is not isolated but greatly influenced by peer and teacher interactions (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991; Marx & Walsh, 1988; Palincsar & Brown, 1984; Resnick, Levine, & Teasley, 1991; Tharp & Gallimore, 1988). Besides the influence of individual beliefs, then, the conceptual change process may be influenced by being situated within different classroom contexts and shaped dramatically by the nature of the interactions between students and the teacher.

The best known conceptual change model in science education, based on students' epistemologies, originated with Posner, Strike, Hewson and Gertzog (1982) and was refined by Hewson (1981, 1982, 1985, 1996), Hewson and Hewson (1984, 1988, 1992), and Strike and Posner (1985, 1992) and applied to classroom instruction by Hennessey (1993). In the conceptual change model, student dissatisfaction with a prior conception was believed to initiate dramatic or revolutionary conceptual change and was embedded in radical constructivist epistemological views with an emphasis on the individual's conceptions and his/her conceptual development. If the learner was dissatisfied with his/her prior conception *and* an available replacement conception was intelligible, plausible and/or fruitful, accommodation of the new conception may follow. An intelligible conception is sensible if it is non-contradictory and its meaning is understood by the student; 'plausible' means that in addition to the student knowing what the conception means, he/she finds the conception believable; and the conception is 'fruitful' if it helps the learner solve other problems or suggests new research directions (Treagust, 2003).

A teacher's beliefs about how students learn can profoundly affect his or her design of instruction, as well as the role of the teacher in carrying out this instruction. If a teacher is concerned with how students make sense of science concepts, that teacher's goals may include how to promote students' deep thinking, rather than students' memorizing of factual and discrete information (Crawford, 2007).

In the conceptual change method which originated from constructivism it tries to identify students' misunderstandings and modify them by replacing new concepts within the process of learning. According to this theory, in the learning process, the role of students is more important than that of teachers and students become autonomous and independent through making concepts in their mind and finding solutions to the problems (Jami & Ahmadi, 2014).

2.3 SCIENTIFIC AND ALTERNATIVE CONCEPTIONS REGARDING NEWTON'S LAWS OF MOTION

Newton's laws deal primarily with the concept of force. Newton's second law of motion states that the **acceleration** of an object is dependent on two variables, namely the **net force** acting on an object and the **mass** of the object. The acceleration of the object is directly proportional to the force and inversely proportional to the mass of the object. The object accelerates in the direction of the net force.

The following is a mathematical expression of Newton's second law of motion:

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$$a = F_{net} / m$$

(F_{net} – net force in Newton, a – acceleration in $m.s^{-2}$, m – mass in kilogram)

The following are a few examples of alternative conceptions related to force and Newton's laws of motion (Hestenes & Halloun, 1995):

1. If an object is at rest, no forces are acting on the object.
2. Only animate objects can exert a force. Thus, if an object is at rest on a table, no forces are acting upon it.
3. Force is a property of an object. An object has force and when it runs out of force it stops moving.
4. The motion of an object is always in the direction of the net force applied to the object.
5. Large objects exert a greater force than small objects.
6. A force is needed to keep an object moving with a constant speed.
7. Friction always hinders motion. Thus, you always want to eliminate friction.

8. Rocket propulsion is due to exhaust gases pushing on something behind the rocket.
9. Velocity is another word for speed. An object's speed and velocity are always the same.
10. Acceleration is confused with speed.
11. Acceleration always means that an object is speeding up.
12. Acceleration is always in a straight line.
13. Acceleration always occurs in the same direction as an object is moving.
14. If an object has a speed of zero (even instantaneously), it has no acceleration.

In physical sciences it is always an option to make use of a demonstration or experiments to establish conflict. It is important that the learners need to express their views and communicate their observations. Class discussions can also be used to further develop the learners' concepts. Through the verbalisation of their conceptual framework and ideas the learners are able to get a clear view of their beliefs and to identify the flaws in their conceptual framework.

What makes Newton's laws and other physics concepts so difficult is that they are constructed upon other important concepts, such as velocity and acceleration, which the learners need to have conceptualised before attempting to conceptualise the main concept. Even the sub-concepts have other concepts they build upon and these concepts are to a large extent abstract. Then we are not even mentioning the cognitive tools needed by the learners during the learning process, such as mathematical tools. During this process the educator should use different strategies to facilitate the learning process, such as making use of "scaffolds" and well-planned assessments to guide the learning process (Scott et al*.,* 1991:5).

2.4 REVIEW ON INTERNATIONAL AND NATIONAL PHYSICS EDUCATION

Conceptual change is based on cognitive conflict and the resolution of conflicting perspectives. It is also based on building on the learners' existing ideas and extension thereof. Conceptual change ensures that learners play an active role in restructuring their knowledge. Furthermore, the design of appropriate interventions by teachers provides scaffolding for the new way of thinking.

Şahin & Çepni (2010) introduce the concept cartoons, animation and the diagnostic branched tree as the teaching materials that can support conceptual change texts related to gas pressure in Grade 8. As the conceptual change texts activate the learners' prior knowledge, concept cartoons will be used to diagnose alternative conceptions. Animation could be used to concretise abstract concepts. The diagnostic branched tree could be used as the springboard for discussion in the classroom that will effect conceptual change. It is the responsibility of the teacher to create an environment conducive for classroom discussion so that learners can understand scientific knowledge.

This was a great conference presentation that enlightened many researchers as far as the learner-teacher support materials for conceptual change are concerned. Conceptual change can now be tackled from this perspective. This is a challenge to physics teachers with a curriculum that puts the learner at the centre of the learning process.

Igwebuike (2012) sought to find out if higher achievers in integrated science taught using the conceptual change pedagogy will achieve significantly better than their counterparts taught using the expository strategy. An experimental group was taught using the conceptual change pedagogy while a second group was taught using the expository method. The students in the experimental and control groups were found to have initial differences in cognitive and affective achievements from the analysis of the pre-tests [$t_{(98)} = 4.93$, $p<0.05$] and [$t_{(98)} = 9.72$, $p<0.05$] respectively. The corresponding multiple classification analysis reveals that high achievers exposed to conceptual change pedagogy had an adjusted cognitive achievement mean score of 17.28, while their counterparts taught by using the expository method had an adjusted cognitive achievement mean score of 17.40 With respect to affective achievement, there was significant difference in favour of high achievers in the experimental group [$F_{(1,97)}= 27.942$, $p<0.05$] (Table 5). This group had an adjusted post-test affective achievement mean score of 62.84 while their counterparts taught through the expository method recorded an adjusted post-test mean score of 58.54.

No statistically significant difference was found between the two groups. However, a significant difference was found in affective achievement between the two groups.

Nwankwo & Madu (2012) examined the effects of the analogy teaching approach on the conceptual understanding of the concepts of refraction of light in physics. Data was collected from 111 physics learners of Nigeria using a pre-test and a post-test. The results showed that the usage of the analogy teaching model had a positive effect on learners. The analysis of data shows that students performed better with a mean of 31.74 and S.D. of 8.49 when taught the concept of refraction using the analogy teaching model than when taught the same concept using the conventional lecture method with a mean of 27.13 and a S.D. of 9.03. Hence, the use of analogy in teaching was able to bring about a significant change in concept acquisition in these students. The results also show that the female students attained conceptual change in SS 2 physics with a mean of 34.09 and a standard deviation of 6.43 better than the males with a mean of 25.29 and a standard deviation of 9.08. That is, the females performed better than the males when taught the concept of refraction of light irrespective of the method used. The researcher recommends that physics teachers and all stakeholders in education should endeavour to incorporate the analogy instructional model as one of the approaches to be adopted in Nigerian secondary schools.

Kaboro et al. (2015) report on the effect of using a dance analogy derived from learners' socio-cultural environment and deals with students' conceptualisation of heat concepts in secondary school physics. The results were compared with those of teaching using the conventional methods. Results showed that teaching the traditional dance analogy led to higher conceptual gains of physical heat concepts compared to teaching using conventional methods. It was recommended that teachers should often consider students' socio-cultural knowledge as the basis for selecting and designing analogies to facilitate conceptual change in teaching abstract science concepts.

On a positive note, the researchers made it clear that what is learnt during instruction depends on learners' prior ideas, the cognitive strategies they have available and their own particular interests and purposes. In addition, their work is logically structured and the topic dealt with has been covered adequately. It reads well and is not confusing. Again, the authors are not controversial. Other writers in the field are engaged as well as in “The results of this research suggest that there is a general trend in the way conceptions are constructed and modified” (Calik, Ayas and Coll 2009; Dikkers and Thijs, 1998; Orgill and Bodner, 2004). Most of all, researchers have used an analogy from all the learners’ socio-cultural environment, the traditional dance of Kenya.

Zeynel (2015) investigated the effect of enriched 5Es model of grade 7 learners’ conceptual change levels about electric current. Within the enriched 5Es model animation, simulations, reputational text and worksheets were employed. A conceptual questionnaire with twelve items was use to collect data. The results indicated that the experimental group out-performed the control group in conceptual understanding. Given the results of the enriched 5Es model in remedying the related alternative conceptions, it is recommended that it should be deployed to teach the other abstract science concepts. A good lesson learnt from this piece of work is that it is important to look for a gap from previous related literature where new research can fit in. The gap was on the use of different teaching and learning activities within the enriched 5Es model to facilitate conceptual change of electric current concepts.

Gyoungho & Taejin’s (2011) study focussed on the relationship between cognitive conflict and responses to anomalous data when learners are confronted with a counter-intuitive demonstration in the form of a discrepant event. Cognitive conflict introduces the first step in the process of conceptual change. On the other hand, Zhon (2012) argues that the outcome of the classroom discourse cannot be oriented to be the replacement of the learners’ intuitive conceptions; rather co-existence between scientific understanding and culture based views is considered to be a reasonable and realistic goal.

Özkan (2012) presents studies that have proven the effectiveness of the conceptual change strategies in recovering learners’ misconceptions. These studies also explain all the details of conceptual change. Özkan & Şelcuk (2013) present examples of the conceptual change texts that physics teachers will benefit from in the teaching and learning about Sound in physics. The conceptual change texts on Sound have not been found in any current literature and this gesture is appreciated. The authors advise that the texts can be used in crowded classrooms.

McGregor (2014) reports on the conceptual change theory that can contribute to a deeper understanding of concepts if there is trans-disciplinarity. The learner must understand the concepts related to the physics topic and other disciplines, and then the learner will be able to solve complex problems. That learner knows how to learn through the inquiry-based approach, learns to do through project based learning, learns to live with others through collaboration on a local and global scale, and learns to discover him/herself. The learner with the 21st century skills will be able to resolve complex problems in life.

Forthcoming is the South African context and Dega (2012) investigates the effect of conceptual change through cognitive perturbation using physics interactive simulations in Electricity and Magnetism. The categorization of students' conceptions was based on the epistemological and ontological descriptions of these concepts. In qualitative results, six categories of alternative conceptions were identified. They were naïve physics, lateral alternative conceptions, ontological alternative conceptions, mixed conceptions and loose ideas. It was concluded that there is a statistically significant difference between cognitive perturbation using physics interactive simulations (CIS) and cognitive conflict using Physics interactive simulations (CIS) in changing students' alternative conceptions. It was suggested that in conceptual areas of Electricity and Magnetism cognitive perturbation through interactive simulations is more effective than cognitive conflict through interactive simulations in facilitating conceptual change and thus should guide classroom instruction in the area. Dega's report flows logically from the introduction to the conclusion and each and every term or process that makes this piece of work understandable is explained in great detail. What the author introduced at the beginning of every chapter is reported on explicitly. The context of the study links well with all the parts of the report. The collection of data, its analysis and the results addressed the research questions. The research questions are used well in guiding the research methodology to the conclusion of the study.

Of all the articles reviewed on the conceptual change approach, Dega is the first researcher who has dug deeper into the evolutionary process of conceptual change than the revolutionary process and the results were positive. The researcher had unequivocally stated that revolutionary processes of conceptual change had shortcomings and many studies attest to that. Secondly, the author gives a detailed account of research instruments used prior, during and after the intervention; and how the intervention will be conducted to slowly and gradually assist the learners in understanding the scientific knowledge better. The recommendations towards the end of the study are a revelation to other researchers. The researcher recommends that researchers should undertake an inclusive, multi-perspective conceptual change research because conceptual change is a complex process.

Rankhumise (2014) reports on the findings of the study that investigated the effect of a bicycle analogy in alleviating alternative conceptions and other conceptual difficulties about electric circuits. The research methodology is not clearly stated. Only one research instrument was used for the pre- and post-tests, and as such this instrument is unreliable because it was not triangulated. The learning strategy perspective supporting the analogy using conceptual change was not stated. Even the learning events that triggered conceptual change were not explained under the intervention stage. However, data analysis showed a normalised gain score of 0,4 between the pre- and post-tests. The mean scores for the pre- and post-tests were 32,4 and 61,6 respectively. The results signified that the instructional intervention involving the use of the bicycle analogy had been effective in significantly alleviating the alternative conceptions and other conceptual difficulties about electric circuits held by the participants.

Kapartzianis (2014) investigated the vocational students' conceptual understanding of electricity by proposing a multi-dimensional and pragmatic approach to conceptual change. Unlike the previous researcher, the mixed methods employed were clearly stated. The research instruments for collecting data were the test, the interview schedule and the field notes to triangulate data collected. The pre- and post-test scores were 34, 87 and 62,52 respectively. Test scores indicated that there was a statistically significant difference between the students' pre- and post-test scores. The majority of students during the post pre-test interviews justified their answers incorrectly, but more than 80% answered correctly in the post post-test interview. Qualitatively, the interviews and field notes were analysed.

In summary, a review of the related literature indicates that alternative conceptions are one of the factors that lead learners to failure in the learning of Physics. To teach physics effectively, alternative conceptions must be spotted and overcome through the usage of an effective teaching approach. The conceptual change approach impacts positively on the teaching and learning of physics at all levels. Studies reviewed above suggest that epistemological, ontological and affective perspectives (multiple perspectives) of the conceptual change model should be employed in order for the conceptual change model to be more effective. This is because the cognitive conflict in the classical conceptual change model could have limitations to provide appropriate conceptual anchors to bridge the gap between the students' alternative conceptions and scientific conceptions. In addition, the learning of science is complex and idiosyncratic. These findings have a significant bearing on my research, which focuses on teaching for conceptual change at the secondary level. The next section presents the teaching of Newton's second law of motion using the conceptual change approach.

2.5 RESEARCH ON NEWTON'S SECOND LAW OF MOTION INTERNATIONALLY AND NATIONALLY

According to Itza-Ortiz, Rebello and Zollman (2003), the most important topic taught in classical mechanics is Newton's laws. Newton's second law, "F= ma," has preoccupied authors for years. Previous research has suggested that students bring their own understanding of the physical world into the classroom making the teaching and learning of Newton's laws a challenge.

A high rate of under-achievement in science at high school level is a cause of great concern across the globe (Fonseca & Conboy, 2006). As a result, some nations, including the United States and Zanzibar, for example, have already started urging all citizens with special emphasis on schools, parents, industry, government and science communities to make a concerted effort against poor performance in science subjects in high schools to ensure that future results would be more encouraging (Science

Daily, 1998; Roach, 2005; Yussuf 2007). It is disturbing to note that corresponding trends of low achievement in science has also been recorded in South Africa (Howe, 2003; Makgato, 2007; Govender, 2009).

2.6 CONCLUSION

This chapter dealt with the underpinning theoretical frameworks of constructivism and conceptual change as well as literature dealing with the concept under investigation. The next chapter provides a detailed explanation of the methodology for the research.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter presents the research design of the study and the plan of activities to collect the data. It presents the sample and instruments used as well as the justification for their selection. The chapter introduces the methodology employed to collect the data to address the following research question: How can the conceptual change approach as a teaching strategy influence the learners' achievement on Newton's Second Law of Motion? Finally, the chapter concludes with the validity, reliability and ethical considerations that the researcher endeavoured to uphold while conducting this study.

3.2 RESEARCH DESIGN

A research design is generally described as a strategic framework for action that serves as a bridge between the research question and the implementation of the research (Durrheim, 2006:34). In other words, it is a logical plan that ensures that evidence obtained enables the researcher to answer the research question. It could also be described as a plan or blueprint that the researcher follows to conduct his research. A mixed method design was employed to answer the research question. The mixed methods design is where the researcher combines quantitative and qualitative research techniques (Johnson and Onwuegbuzie, 2004). The strength of quantitative research lies in its reliability (repeatability) – the same measurements should yield the same results time after time (Babbie and Mouton, 2001). The strength of qualitative research lies in validity (truth) – research using a variety of data collection instruments should lead to in-depth understanding of social phenomena (Babbie and Mouton, 2001). The research design included a case study, a pilot study and sampling as explained below.

3.2.1 CASE STUDY

This study adopted a single case-study design. A case study is defined as "an exploration of a bounded system or a case over time through detailed and in-depth data collection involving multiple sources of information and in-depth data collection involving multiple sources of information rich in context" (Creswell, 1998:272). Similarly, Yin (1989:23) defines a case study as "an empirical inquiry that investigates a contemporary phenomenon within its real life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used. A case study does not rely on any particular method of data collection; therefore, any method of data collection can be employed (Merriam, 1988; Yin, 2007).

Creswell (1994) and Zainal (2003) concur that a case study selects a small geographical area or limited number of individuals as subjects of study. In this research the researcher used a case study strategy because the sample consisted of grade 11 physical sciences learners from the same school. The rationale for using this method is that of its suitability to undertake an in-depth examination of a real world problem.

3.2.2 SAMPLING

Wright (2011) defines sampling as a procedure a researcher uses to gather people, places or things to study. The study was conducted in a rural secondary school in Mthatha district in the Eastern Cape. A purposive sampling method was used in the study. There is only one class in the school doing physical sciences in grade 11 consisting of 33 learners. Grade 11 physical sciences learners were used in the case study. The class consists of 33 learners, so all learners were part of the pre-test, intervention and the post-test.

Table 4: Sample for the study

PARTICIPANTS	SAMPLE SIZE	TECHNIQUE
Learners for the lesson	33	Total population
Learners for the group interviews	33 (11,11,11)	Total population

3.3 DATA COLLECTION PLAN

For the purpose of this study a mixed method design was used, i.e. both qualitative and quantitative data were collected. The data collection plan followed five steps as outlined below. The plan includes a pilot study, pre-test, intervention, post-test and focus group interviews.

3.3.1 PILOT STUDY

A pilot study was included in the research design prior to data collection to determine the feasibility of the interview schedule and the pre-test in terms of the relevance of the questions and applicability of the content. This utilisation of pilot studies is in line with Huysamen (cited in Strydom, 2000), who posits that the aim of pilot studies is to investigate the suitability and feasibility of the research instruments. The pre-test was given to grade 11 learners of the neighbouring school and they gave feedback on their understanding of the questions. Their responses showed that they understood the questions.

3.3.2 DATA COLLECTION PROCESS

The process of data collection followed a four step approach which corresponded to the research sub-questions:

i) *What was learners' initial understanding of Newton's second law of motion?*

A pre-test was administered to the learners in the form of multiple-choice questions. The pre-test (Appendix A) was given to the learners to find the level of understanding they have on Newton's second law of motion and the misconceptions they might have on the topic. A set of questions extracting information about Newton's second law of motion was given to the learners. The pre-test questions were categorised as follows:

- Definitions of net force, velocity and acceleration
- Calculations of net force, time, acceleration
- Unit of measurement for force, mass and acceleration

ii) *How was the conceptual change approach implemented to teach Newton's second law of motion?*

An intervention was done by the educator to emphasise the steps of the conceptual change framework as suggested by Posner at al (1982). The intervention was in the form of an inquiry type of lessons and it was based on the learners' responses in the pre-test. The intervention was administered over three lessons.

Lesson 1- Dissatisfaction

During this lesson, learners were given an activity to answer with the help of textbooks, Google, etc. The learners first tackled the task individually, then formed groups and discussed their responses. Then each group presented its responses and interacted with the members of the other groups under the guidance of an educator.

Lesson 2 – Intelligibility and plausibility

In the next lesson, learners were requested to investigate the relationship between acceleration and force. As the learners were doing the experiment (Appendix B), they observed and recorded the values in a table. The ability of the learners to observe and record showed their understanding of the experiment. Then the values were used to draw graphs showing that learners were able to make sense of Newton's second law of motion.

Lesson 3 - Fruitfulness

In lesson 3 the learners were given exercises which involved real life situations, for example, calculations of acceleration, distance and time.

As the intervention stage was in progress, all the lessons were video-taped for observation purposes. An observation schedule was used to collect more data.

iii) *What was learners' understanding of Newton's second law of motion after the conceptual change lessons?*

A post-test was given to the learners to test if there had been any change in the understanding of Newton's second law of motion. The test was similar to the pre-test. Learning gains were calculated from these results.

iv) *What was learners' perception of the conceptual change approach as a teaching strategy?*

An evaluation process of conceptual change was conducted. The learners were subjected to interviews where they expressed their views about the conceptual change approach. The learners were asked to give reasons why their scores in the pre-test and post-test were different. Then questions to display their understanding of Newton's second law of motion were asked, that is, calculations and application in real life situations.

Table 5 below presents a summary of the data collection methods used in this study.

Table 5: Methodological framework

RESEARCH QUESTION	RESEARCH METHOD	INSTRUMENT	RESPONDENTS	ANALYSIS
How can teaching using a conceptual change approach improve the learners' achievement in Newton's second law of motion?				
STEP 1:	Pre-test	Test	Learners	Marks
STEP 2	Intervention Video-taping	Lessons plan • Dissatisfaction exercise • Intelligibility and plausibility An investigation • Fruitfulness exercise Observation schedule	Learners	Thematic analysis Write-up using thick descriptions Discussions
STEP 3	Post-test	Test	Learners	Marks
STEP4	Interview	Interview- schedule	Learners	Coding

3.4 DATA COLLECTION PROCEDURES

The following research data collection procedures were used in this study:

3.4.1 INTERVIEWS

According to Ndagi (1984) interviews are used when a researcher wants to obtain reliable and valid information in the form of verbal responses from respondents in order to confirm or reject hypotheses. Focus group interviews were conducted using an interview schedule. Learners were divided into three groups of 11 each and the same set of questions was asked. A qualitative interview is an interaction between an interviewer and a respondent with the interviewer pursuing a certain direction with the interviewee in order to elicit certain information from the respondents.

A **focus group interview** involves asking open-ended questions based on the topic being investigated. The advantage of open-ended questions is to provide the opportunity for both the interviewee and interviewer to cover the topic in more detail and depth. Through these open-ended questions, the researcher can prompt the interviewee for more detail or clarification.

The focus group interview occurs when a group of people is interviewed simultaneously to discuss a topic of interest. The main advantage of focus groups is the opportunity to observe a large amount of interaction on a topic with the minimum of time required. It is also easy to assemble the focus group. According to Babbie and Mouton (2001:292), an advantage of focus groups is the ability to observe the interaction within the group. The group discussions provided direct information about the issues on which the group differed and on those upon which they agreed. A focus group is a form of qualitative research in which a group responds to questions. In such discussions, the interviewer asks group members specific questions about a topic, usually after a great deal of the research has been concluded (Denzin & Lincoln, 2005). The advantage of using focus group discussions is that they generate data and insights which would be less accessible without the interaction found in a group setting (Babbie & Mouton, 2001; Maree, 2007). In addition, they are inexpensive, provide immediate responses to questions raised, and are cumulative and elaborative (Maree, 2007). The disadvantages of such discussions are that the researcher has less control over a group and that time can be spent on issues which are irrelevant to the topic discussed (Patton, 2002). A further disadvantage of a focus group is that it can be dominated by outspoken individuals who make it difficult for the less outspoken members to participate.

In this study, the researcher gave the students chances to speak, and the less assertive students in particular were encouraged. Speaking in their first language was permitted. In this study, focus groups interviews were conducted after the learners had written the pre- and post-tests and had undergone the intervention programme. They were also used as a form of triangulation to validate the information obtained through other data collection tools. This section explored the application of these data collection techniques

3.4.2 OBSERVATIONS

In research, observation is defined as watching of behavioural patterns of people in certain situations to obtain information about the phenomenon of interest (Burke & Larry, 2012). The observer should attempt to be unobtrusive so as to affect what is being observed. Observation is an important way of collecting information about people because people do not always do what they say they do. In this study the learners were observed in class when doing practical activities and during the intervention lesson.

3.5 DATA ANALYSIS

Data analysis is described as a systematic process of selecting, categorising, comparing and interpreting data by sorting or organising collected data in order to verify it, make sense of it, and ultimately to be able to draw conclusions from it (Patton, 2002). The data was analysed statistically. The marks of learners from the pre-test and post-test were compared and tabulated. The video of the intervention was analysed using an observation schedule and a thick description of the intervention was provided. The interview data was analysed manually and qualitatively, and the learners' responses were audio-taped and transcribed. The interview was conducted in Xhosa then translated into English. The data was cleaned, analysed and categorised into themes. The themes were questions based on tests and experiments conducted during the lesson and knowledge gained in class.

3.6 VALIDITY

'Validity' refers to the "degree to which the measuring instrument measures what it is supposed to" (Rossouw, 2005:123). To ensure validity three instruments were used to collect two sets of data for triangulation. This study used a variety of data collection methods, such as interviews, questionnaires and focus group discussions to validate and cross-check findings (Patton, 2002; Babbie & Mouton, 2001). Triangulation tests the consistency of the findings obtained through different methods (Patton, 2002;

Babbie & Mouton, 2001). Using a combination of methods increases validity, since the methods can complement each other. The questions asked during interviews were clear, focused and aligned with the research question. The interviews were audio-taped, thereby capturing every word the respondent said. After transcription was done, the report was given back to the respondents to ensure that they had been quoted correctly. To ensure validity in this study, summaries of the interviews were given to the key participants for comments.

3.7 RELIABILITY

Reliability refers to whether the tool would yield the same results if it was applied repeatedly to the same subjects under the same or similar conditions. It is therefore concerned with the consistency of the tool in measuring what it claims to measure. A reliable tool is one which yields the same results each time it is used. Reliability is the degree to which an instrument produces stable and consistent results (Cozby, 2001:6). Reliability is generally understood to concern the replicability of research and the obtaining of similar findings if another study using the same methods was undertaken (Lewis & Ritchie, 2003). Reliability was ensured by piloting the research instruments, that is, it was tested with learners who are not part of the sample. The instruments were given to grade 11 learners doing physical sciences in the neighbouring school. More than one instrument was used in this study (interviews, observations and tests) to triangulate the findings.

3.8 ETHICS

Transparency was maintained throughout. After the interviews with the three focus groups, summaries of the interviews were given to the participants for comments and validation. The students also saw their own scores from the pre- and post-tests. The following steps were taken to ensure that the study conforms with the ethical standards laid down by the Senate Research Committee of the University of the Western Cape:

- Names of schools involved will be kept anonymous

The interviews were anonymous with respect to the subjects' names. When conducting research, one needs to be guided by the ethics associated with it. According to Oppenheim (1996:83), "the basic ethical principle is that no harm should come to the respondents as a result of their participation in the research". Following this assertion, the researcher made maximum efforts to ensure adherence to the necessary ethical standards.

- Firstly, the research proposal along with all data collection tools were presented to and approved by the University of the Western Cape's Senate Research Committee before data collection. The process of data collection commenced immediately upon approval of the research proposal and instruments.
- Secondly, approval and informed consent were sought from the participants and relevant institutions. Approval for the study was obtained from the University of the Western Cape (Appendix 1) and the Eastern Cape Education Department (Appendix 2). This was to ensure that no harm was done to the study participants (Babbie & Mouton, 2001). The respondents were presented with a consent form and a brief introduction to the study (see Appendix 1). The principals' permission and that of the SGB were sought (Appendix 3). Learners' consent forms were completed (Appendix 4) and parents' consent forms were signed (Appendix 5).

  This enabled them to make informed decisions when consenting to the study. All participants remained anonymous throughout the analysis of the data (Creswell, 2009). Confidentiality and anonymity were maintained throughout and all participants were advised of this. The researcher removed any details that might be harmful to the participants. The participants were, however, cautioned that their words could be quoted in the final report, but that their names would not be used in conjunction with the quotation.

3.9 CONCLUSION

This chapter examined the research methodology and techniques used in the study. The next chapter provides a more detailed presentation of the findings of the study.

CHAPTER 4

RESEARCH FINDINGS

4.1 INTRODUCTION

The previous chapter outlined the methodology employed to collect data. This chapter will provide the findings to address the research question. The chapter is therefore organised around the data collected to answer the following main research question and sub-questions:

How can teaching using a conceptual change approach improve the learners' achievement in Newton's second law of motion?

- What was learners' initial understanding of Newton's second law of motion?
- How was the conceptual change approach implemented to teach Newton's second law of motion?
- What was learners' understanding of Newton's second law of motion after the conceptual change lessons?
- What was learners' perception of the conceptual change approach as a teaching strategy?

4.2 WHAT WAS LEARNERS' INITIAL UNDERSTANDING OF NEWTON'S SECOND LAW OF MOTION?

4.2.1 Pre-test

It was explained to students that, though they were going to write the test, their marks were not going to affect their performance in anyway and the marks were going to be treated with confidentiality. The learners were seated individually so that they did not influence one another.

The learners were given the pre-test to write so as to find out their prior knowledge of Newton's second law of motion (see Appendix A). The duration of the test was one hour and all the learners completed within the prescribed time. After they had finished writing the test, the answer sheets and question papers were collected and kept in a safe place. The answer sheets were marked and marks recorded. The question-by-question analysis was done to prepare an intervention lesson based on the misconceptions of the learners. Table 4 below shows the marks obtained by the learners on the pre-test. Table 6 shows the number of learners at different levels in terms of percentages. In the pre-test 15 learners obtained level 1 and none of the learners managed to get level 7. Eleven learners out of 28 ranged between 40% and 70%, which is less than half of the class.

Table 6: Learner achievement in the pre-test

LEVELS	NO. OF LEARNERS
1(0-29)	15
2(30-39)	2
3(40-49)	4
4(50-59)	4
5(60-69)	1
7(70-79)	2
8(80-100)	0

Figure 3 shows the learners' performance in the pre-test. The majority of the learners achieved between 0 and 29%. Only two learners achieved between 30 to 39%. Eight learners managed to get 40 to 59%.

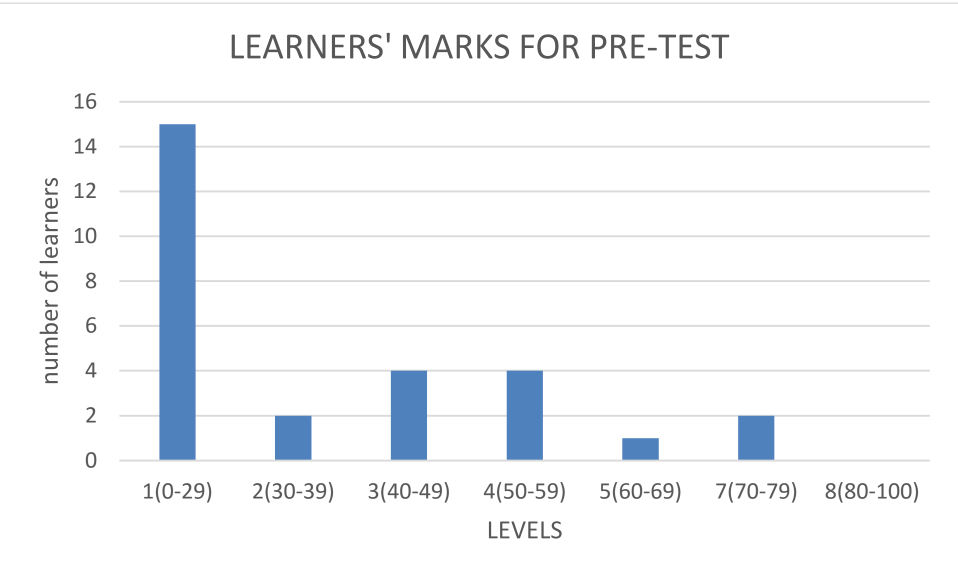

Figure 3: Average marks per question in P1 for Physical Sciences

4.2.2 **Question by question analysis**

The learners' performance was generally poor as there was no question mastered by all of them. Twenty-four learners got question 1 correct and this showed clearly that most of the learners know the unit for measuring force. Only two learners managed to get the correct answer for question two. This question dealt with constant velocity related to net force. 26 learners answered question 3 correctly, which was a straightforward question asking about the formula for Newton's second law of motion. Question 4 was testing learners' understanding of the term 'net force' and about 20 learners got this one right. Question 5 involved calculations, which needed learners to use a formula to solve the problem. Only one learner solved the problem. Learners were unable to identify forces acting on the object. This was evident in their performance as only three learners could get question 6 correct which asked learners to name forces acting on an object. Question 7 requested memorisation as it was asking about the definition of acceleration and 27 learners answered correctly. Two learners answered question 8 correctly. 15 learners managed to get question 9 correct and this question involved manipulating the formula for Newton's second law of motion. The last question tested learners' understanding of inverse and direct proportion in Newton's second law of motion and most of the learners failed to get this question right as only two learners had answers that were correct.

4.3 HOW WAS THE CONCEPTUAL CHANGE APPROACH IMPLEMENTED TO TEACH NEWTON'S SECOND LAW OF MOTION?

Due to poor performance of learners in the pre-test, the conceptual change approach was used as a teaching method to improve learners' understanding of Newton's second law of motion. Posner et al. (1982) hypothesised that there are four conditions for conceptual change, namely dissatisfaction, intelligibility, plausibility and fruitfulness.

4.3.1 **Dissatisfaction**

The learners must first realize that there are some inconsistencies and that their way of thinking does not solve the problem at hand. In order to introduce dissatisfaction with their current concepts, the following lesson was implemented:

In the first lesson, the educator introduced the lesson by citing a scenario where learners interacted with one another and with the educator. The scenario is as follows: Two dogs, A and B, are pulling the same bone with the same force but in opposite directions. A simulation was shown to the learners using a PowerPoint presentation.

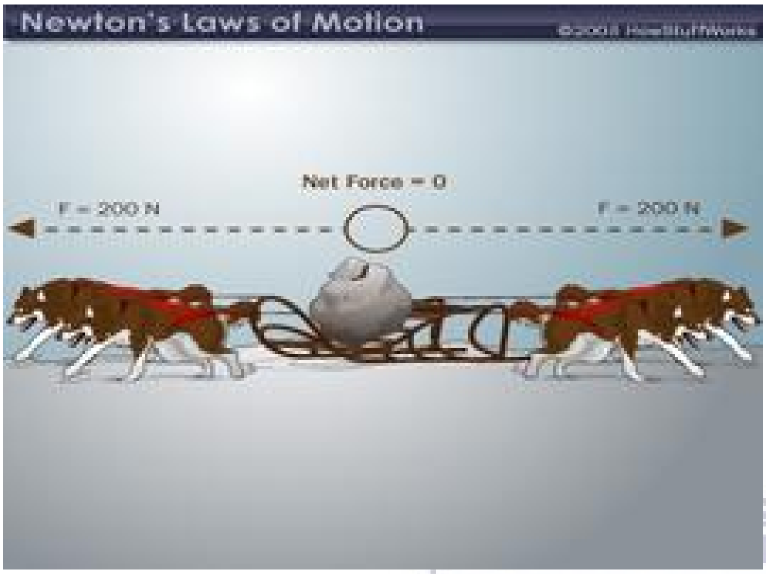

Figure 4: Simulation of dogs applying force to an object

In this simulation the magnitude of the forces applied by the dogs was given. The educator asked the learners which dog will get the bone, and why. The responses were as follows:

> Dog A will get the bone because it is bigger than dog B [Learner 1]
> The bone will break in half [Learner 2].

The educator intervened to direct the focus of the learners to the topic at hand which was dealing with forces. One of the learners responded:

> Not a single dog will get the bone because the forces are equal but in opposite directions, therefore they cancel one another [Learner 3].

Then the educator explained that although the bone is stationary there are forces acting on the bone but they are balanced, that is why they don’t have an effect on the object. Therefore, the resultant force acting on the bone is equal to zero. The educator defined resultant force as the sum of all the forces acting on an object and the formula for calculating resultant force was given as $F_{net} = ma$.

The educator asked the learners to give the units for measuring the three variables in the formula. The learners responded and gave the units for force as newtons (N), mass – kilograms (kg) and acceleration – metres per second (m. s^{-2}). As the learners were giving the units the educator wrote them on the board below the formula for calculating the resultant force. This part allowed learners to understand that $1N = 1kgm.s^{-2}$.

The educator asked learners what did they understand about acceleration.

> Acceleration is an increase in speed [Learner 1].

The educator reminded the learners about the difference between vector and scalar. It was also emphasised that when defining terms learners must always think about a formula for that particular concept. The formula for calculating acceleration given by the learners was written on the board as:

$$a = \frac{vf - vi}{\Delta t}.$$

The educator asked the question again: What is acceleration? One learner responded:

> Acceleration is the rate of change in velocity [Learner 9].

The educator explained that if there is no change in velocity (constant velocity) acceleration is equal to zero. If $a = 0$ that means $F_{net} = 0$.

Two examples were written on the board which gave the learners an opportunity to play around with the formula for calculating resultant force:

Example 1

A cyclist of mass 55kg rides a bicycle of mass 15kg. When starting, the cyclist provides a force of 175N. Calculate her acceleration.

Example 2

A minibus of mass 1500 kg is travelling at 20m.s-1. The driver sees a red traffic light ahead, and slows to a halt in 10s. Calculate the force that the brakes must provide to do this.

The learners first tackled the task individually, and then formed groups and discussed their responses. Having worked individually, each group presented its response and then the groups interacted with each other with the guidance of an educator.

The educator moved around and marked the learners' books as they were solving the problems given. As the educator was marking the learners' work, it was clear that some learners were unable to understand the formula and that led to wrong calculations. The educator solved the problems together with the learners as remedial work. When discussing learner challenges, the learners analysed the questions themselves by stating the given information. They also grasped the skill to choose a suitable formula for solving the problem. The concepts became clear as the learners were interacting with the educator and each other. After comparing their solutions and the problems with what they had indicated in the pre-test, it became clearer that learners were dissatisfied with their solutions in the pre-test.

4.3.2 Intelligibility

Posner et al. (1982) argued that for learners to accommodate a new concept, they must find it intelligible. The concept should not only make sense, but the learners should also be able to provide the argument and ideally be able to explain that concept to other classmates. In order to address intelligibility, the following lesson was implemented:

PRACTICAL INVESTIGATION 1

Learners investigated the relationship between acceleration and force. The learners were given the following apparatus to perform an investigation: Trolley, trolley track, ticker-timer attached to electricity supply, four lengths of ticker-tape, four identical weights and a rope. As the learners were doing the experiment (see Appendix B), they observed and recorded the values in a table. The acceleration of the trolley was determined by analysing the ticker-tape.

The following table was given to learners to fill in:

Table 7: Table of results for the experiment

Ticker-tape	Force (force-units)	Acceleration a ($m.s^{-2}$)	F/a
1	1		
2	2		
3	3		
4	4		

Immediately the learners finished filling in the table, they were asked to write down their observation of the relationship F/ a as calculated on the table.

The educator referred learners to the table and asked them to compare the values of force and acceleration. The learners were able to state that as the force increases, acceleration also increases. The educator explained that this means that acceleration is directly proportional to the force and showed learners the mathematical expression:

$$a \alpha F$$

PRACTICAL INVESTIGATION 2

The learners conducted an experiment investigating the relationship between acceleration and mass when force is kept constant (Appendix C). The educator provided the learners with the apparatus and a worksheet for doing the experiment. On the worksheet the following concepts were given: aim, apparatus, method, table for recording values and questions to answer. The table used to record values was as follows:

Table 8: Values of acceleration and mass

Ticker-tape	Force (N)	Mass (Trolley-units)	Acceleration ($m.s^{-2}$)	1/mass
1	3,5	1		
2	3,5	2		
3	3,5	3		
4	3,5	4		

The ability of the learners to observe and record the readings on the tables provided showed their understanding of the experiment and ability to manipulate the apparatus. This indicated that they were thinking about the concepts and able to deliberate their understanding of it in the practical groups. Therefore, the process of intelligibility was addressed.

4.3.3 Plausibility

The new conception must be plausible for it to be accommodated. The new concept must make more sense than the old concept. It must have (or at least appear to have) the capacity to solve the problem.

The learners were asked to draw an acceleration vs force graph with given values. Then learners drew conclusions on the plotted data, implying that learners were able to make sense of the experiment. For enrichment purposes learners were asked to use the same values to draw graphs of acceleration vs mass and acceleration vs $1/mass$.

Subsequently, the learners plotted the graphs and they were asked to write conclusions relating acceleration and mass. The learners stated that as mass increases, acceleration decreases. They were also able to state that acceleration is directly proportional to the inverse of mass with the mathematical expression for this relationship as follows:

$$a \; \alpha \frac{1}{m}$$

The educator explained the relationship between acceleration, mass and force combined.

$$a \; \alpha \frac{F}{m}$$

This can also be rearranged in this way: F α ma

A proportionality constant is introduced, k, then Fnet =kma and where k=1, we get that: Fnet = ma**.**

Then the learners were given a simple example below to apply the formula for Newton's second law of motion.

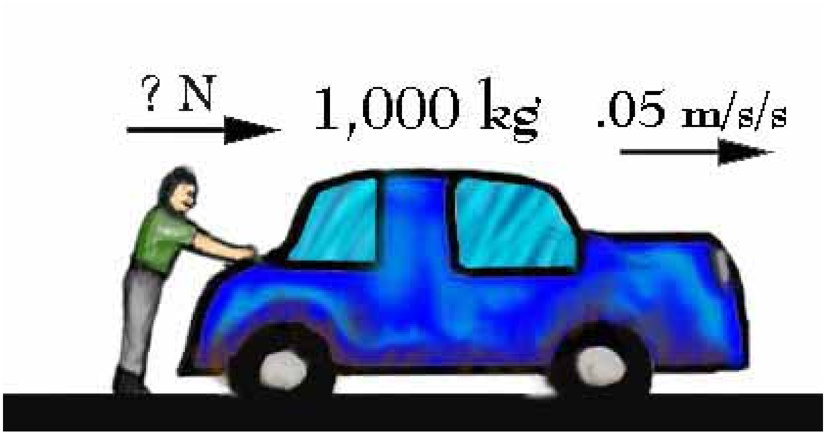

Figure 5: Diagram showing force and acceleration

F_{net} = ma

= 1000 x 0.5

= 500N

Learners found the application of the formula to an elementary example as a workable one as many of them readily solved the problem. They found the application of formula in the example as a plausible solution to similar problems that were given as homework.

4.3.4. Fruitfulness

For the new concept to be accommodated, the learners need to find it fruitful in the sense that this concept should have the potential to be extended to other incidences, and open up new areas of inquiry.

In lesson 3 the learners were given exercises which involved real life situations, for example, calculations of acceleration, distance and time taken by an empty and loaded taxi to stop. The example of using a taxi in the problem placed the concept within their own context, something they could relate to.

Exercise

The mass of a minibus with the driver is $1,5 \times 10^3$ kg. Assume that the passengers have an average mass of 50 kg each. The driver is moving at a speed of $30 m.s^{-1}$ when he notices that the traffic lights ahead have turned to red. He applies a force of $9,00 \times 10^3$ N on the brake pedal.

a) Calculate his deceleration if the taxi is empty (that is, there are no passengers).

b) How far must he have been from the traffic lights if he were able to stop in time?

c) How long will it take him to stop?

d) Calculate the deceleration if the taxi is carrying 10 passengers.

e) How will the stopping distance change if the minibus is carrying 10 passengers?

This activity gave learners an opportunity to apply their knowledge of Newton's second law in real life situations. From the calculations it was clear that acceleration of an empty taxi is greater than the acceleration of the taxi when it is loaded with passengers. The distance needed by the taxi to stop when it is empty is less than when it is loaded. The educator asked the learners why it is dangerous for a taxi that is full of passengers to move at a high speed and to base their answer on the calculations above.

> The taxi will take a longer time to stop [Learner 1].
> It is not easy for the taxi to stop [Learner 2].
> Many people will die if it is involved in an accident [Learner 3].
> The driver will not be able to control the taxi [Learner 4].

4.4. WHAT WAS LEARNERS' UNDERSTANDING OF NEWTON'S SECOND LAW OF MOTION AFTER THE CONCEPTUAL CHANGE LESSONS?

In the post-test the number of learners who scored level 1 decreased by a difference of 6.

Table 9: Learner achievement in post-test

LEVELS	POST-TEST
1(0-29)	9
2(30-39)	5
3(40-49)	4
4(50-59)	2
5(60-69)	5
6(70-79)	0
7(80-100)	3

There were 3 learners who got level 7. Nine learners still got level 1 even after the intervention lesson, that is, in the post-test as represented in Table 7. The graph below (Figure 4) shows the performance of learners in the post-test. Thirty two (32%) percent of the learners got level 1, 18% of the learners managed to get level 2, 39% of the learners got marks ranging from level 3 to 5 and 11% of the learners performed very well and got level 7.

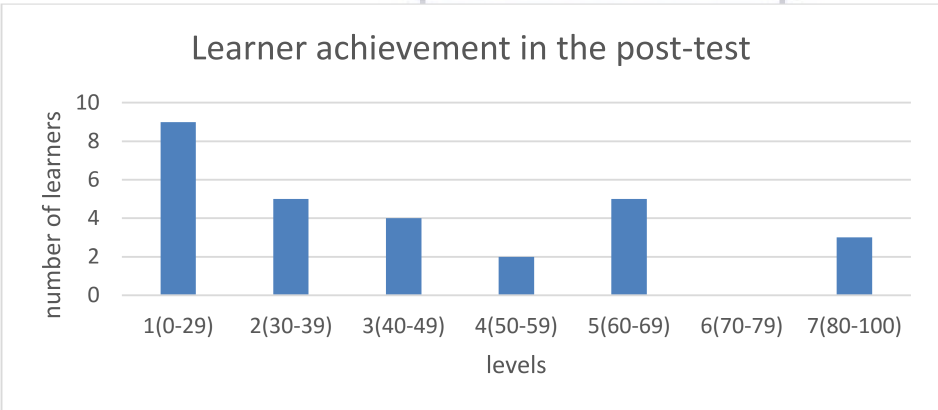

Figure 6: Learner percentages for post-test

4.5. INTERVIEWS

The stages in analysing the data collected from an interview in this study are as follows:

- A transcript of the data collected was made. The verbal data was transcribed verbatim immediately after the interview.
- Familiarisation with the data was accomplished through reading and re-reading the data.

- Data, which seemed similar, were grouped together. This is called the coding of the data.
- Similar codes were grouped together to form categories.
- Codes and categories were compared to find similarities or differences.
- The last stage was the description of the data and the interpretation of the data.

During interviews, learners were divided into three focus groups, A B and C, of 11 learners each. When the interviews were conducted, focus group interview A (FI_A) – Learner 9 stated that in the pre-test they scored low marks because they were not aware that they were going to write a test so they were not prepared. Some attempted to answer but incorrectly, as they thought they understood the concept.

Table 10: Focus groups with learners' coding

Focus groups	Learner coding
A	L_1-L_{11}
B	L_1 –L_{11}
C	L_1 – L_{11}

The focus group interview was divided into the following themes based on the responses of the learners: definitions of concepts, application of Newton's second law of motion in real life situations, understanding of concepts and examples, attitude of learners towards Newton's second law of motion.

- Definition of concepts:

  Acceleration is the change in velocity divided by change in time. [FI_B – L 5]

The educator explained that change in time is also known as the rate, and then asked the learners to rephrase the definition.

Acceleration is the rate of change in velocity. [FI_C – L 2]

The learners were asked to give the units for measuring acceleration.

$m.s^{-1}.\ s^{-1}$ [FI_D- L3]

$m.s^{-2}$ [FI_C – L 2]

The learners were asked to define the resultant force. These were the learners' responses:

> Resultant force is a combination of all the forces acting on an object [FI_C- L11].
>
> Resultant force is the sum of all the forces acting on an object taking into consideration their direction [FI_B – L8].

- Application of Newton's second law of motion in real life situations:

The learners were asked to apply Newton's second of motion in real life situations. Most learners could not answer this question and only two learners made an attempt and their responses were as follows:

> Drivers must maintain the required speed in various areas especially the loaded trucks as it needs a longer distance to stop [FI_C – L_{10}].
>
> It is important for people in a car to wear safety belts so as to balance the forces acting on them [FI_B – L_{11}].

- Understanding of concepts and examples:

The educator asked learners to explain direct proportion and inverse proportion using Newton's second law of motion. The learners' responses were as follows:

> Acceleration is directly proportional to the resultant force and inversely proportional to mass [FI_B – L_7].

The educator asked the learners to simplify the relationship between force, acceleration and mass.

> An increase in acceleration increases the resultant force and decreases the mass [Fic – L_3].

- Learners' attitude towards Newton's second law of motion

The learners were asked how confident they were in solving problems dealing with Newton’s second law of motion.

I am confident enough to solve problems dealing with Newton’s laws of motion [FI_A – L_2].

4.6 CONCLUSION

In this chapter results obtained from the pre-test, intervention and interviews were explained in detail. In the next chapter the results will be analysed and discussed.

CHAPTER FIVE

DISCUSSION

5.1 INTRODUCTION

As outlined in the previous chapters, the purpose of the study was to find out how the conceptual change approach could be used to improve learners' performance in Newton's second law of motion. In the previous chapter the findings of the study were presented.

This chapter discusses the findings linking them to relevant literature. The discussion presented revolves around the research sub-questions which are:

i) What was learners' initial understanding of Newton's second law of motion?
ii) How was the conceptual change approach implemented to teach Newton's second law of motion?
iii) What was the learners' understanding of Newton's second law of motion after the conceptual change lessons?
iv) What was the learners' perception of the conceptual change approach as a teaching strategy?

This chapter therefore focuses on the interpretation and analysis of data collected from the pre-test and post-test, the intervention and interviews.

5.2 WHAT WAS THE LEARNERS’ UNDERSTANDING OF NEWTON’S SECOND LAW OF MOTION INITIALLY AND AFTER THE CONCEPTUAL CHANGE LESSONS?

Table 11: Comparison between pre-test and post-test

LEVELS	Pre-test	POST-TEST
1(0-29)	15	9
2(30-39)	2	5
3(40-49)	2	4
4(50-59)	4	2
5(60-69)	1	5
6(70-79)	2	0
7(80-100)	0	3

In the table above, the first column is an indication of levels from 1 to 7and in brackets the corresponding percentages are shown next to the levels. The second and third columns are displaying the number of learners in the pre-test and post-test according to the percentages they scored.

After the intervention the number of learners ranging between 0 and 29%, that is level 1, decreased from 15 to 9. In the pre-test there were 2 learners who got level 2 and this increased to 5 learners in the post-test. There were 2 learners in the pre-test who scored between 40 and 49% whereas in the post-test they were 4. Learners between 50 and 59% decreased from 4 to 2 in the post-test. Then in level 5, which is 60 to 69 %, in the pre-test there were 2 learners and in the post-test no learner achieved this level. In the pre-test there was no learner who managed to get level 7 whereas in the post-test 2 learners got level 7.

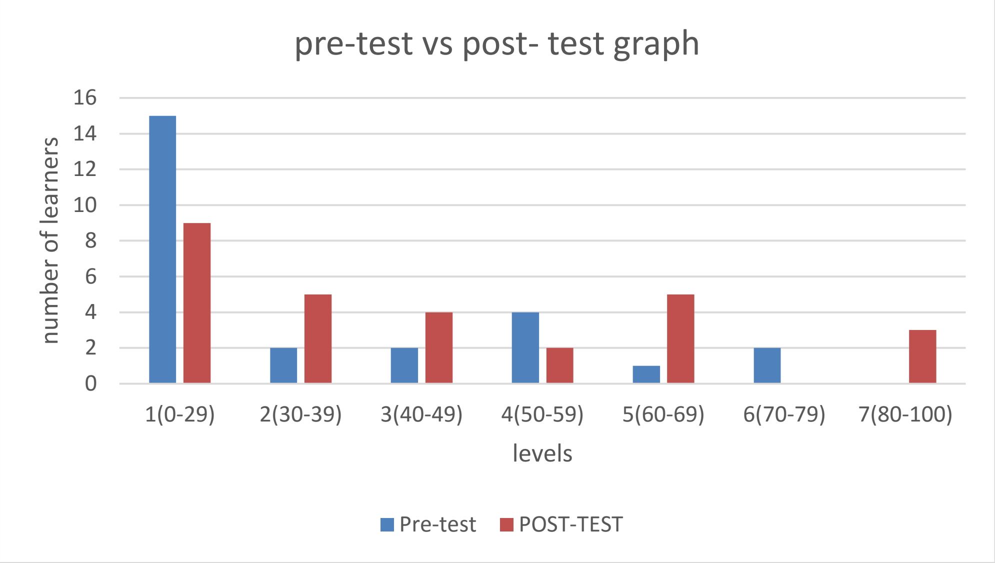

Figure 7: Graph of comparison between pre-test and post-test

The graph shows clearly that the learners' marks have improved. Between 0 and 29 the graph for the post-test is shorter than the graph for the pre-test. This means that the number of learners within this range has dropped drastically. It is clear in the graph that from level 2 to 7 there has been an increase in the number of learners who scored these marks in the post-test than in the pre-test. In the pre-test the highest mark obtained by learners ranged between 70 and 79%. But after the intervention there were learners who scored high marks and got level 7. This change in the marks of learners means the learners have improved in their understanding of Newton's laws of motion after the intervention.

The pre-test is composed of ten questions dealing with Newton's second law of motion. The questions were divided into four categories, namely, unit of measurement of force, definitions (net force, acceleration, velocity and mass), calculations and identifying forces acting on an object.

- *Unit of measurement of force*

The question asked what the unit of measurement of force is. 25% of learners got the answer right. Three learners gave the response as $m.s^{-1}$. Five learners' responses were kg. m. s^{-1}. It was clear that learners do not know the formula for calculating force as it links directly to the unit of measurement of force. In the post-test 52% of the learners managed to get this answer correct.

- *Calculations*

One question asked about the calculation of acceleration given initial velocity, final velocity and time. Learners were unable to choose a suitable formula for solving the problem. Only 38% got this question correct in the pre-test. 40% of the learners answered this question right in the post-test.

Another question involved the calculation of time given acceleration, displacement and initial velocity. In the pre-test 32% of the learners were correct and in the post-test 48% of the learners got the answer right. The learners showed inability to make the subject of the formula of the required physical quantity.

In the next question learners were required to calculate time given initial velocity, acceleration and displacement. 35% of the learners in the pre-test were correct and 52% of the learners in the post-test achieved this question. It was clear in these questions that learners have a problem applying formulae.

In another question, learners were required to find the acceleration given force and mass. This question is the basis for Newton's second law of motion. 43% of the learners in the pre-test were correct and in the post-test 62% of learners were correct.

- *Identifying forces acting on an object*

In this question the learners were asked to identify forces acting on the object. 37% of learners were able to name the horizontal forces acting on the object in the pre-test and in the post-test the percentage increased to 47%. This question showed that learners were able to identify different forces acting on an object which will add up to the resultant force.

- *Definitions*

The learners were asked to define acceleration. In the pre-test 42% of learners were able to answer the question and in the post-test the number of learners who got this question right increased to 60%. In this question the performance of the learners was better in both the pre-test and post-test, showing that learners are able to memorise. Their performance declines when it comes to questions involving calculations and application of formulae.

Table 12: learners' marks in the pre-test and post-test

Learners	pre-test %	post-test %
L1	10	24
L2	35	29
L3	56	82
L4	18	23
L5	29	45
L6	41	36
L7	24	50
L8	53	64
L9	43	65
L10	53	54
L11	26	61
L12	29	33
L13	25	39
L14	71	88
L15	17	28
L16	43	60
L17	17	18
L18	26	42
L19	75	83
L20	27	35
L21	37	32
L22	44	45
L23	60	65
L24	54	44
L25	10	26
L26	15	26
L27	23	25
L28	19	25

Table 11 above shows the marks, in the form of percentages, scored by each learner in the pre-test and post-test. Generally, the performance of the learners improved after the intervention. Two learners showed a decrease in marks from pre-test to post-test. The reason for this might be the fact that the learners got confused. One of the learners missed some of the lessons as the learner was not at school due to social problems. This confirms that conceptual change approach is an effective strategy for teaching.

5.3 HOW WAS THE CONCEPTUAL CHANGE APPROACH IMPLEMENTED TO TEACH NEWTON'S SECOND LAW OF MOTION?

The learners were given an activity, in the form of a scenario, to make them realise that they have misconceptions and their understanding of Newton's second law of motion is not scientific. This was achieved through learner-learner and learner-educator interaction. In this activity the learners responded differently on the questions cited by the educator. This means that an inquiry method was used so that learners could reach a stage where they were not satisfied with their responses on their own.

During the intervention, the misconceptions picked up on the pre-test were addressed as the learners were actively involved in class. For example, when they watched the simulation of the two pairs of dogs pulling on the bone but in different directions they could see that the bone was not moving. Then when the educator asked them probing questions about the resultant force the learners suggested various answers, some of which were not scientifically correct. Through interaction within themselves and the educator the learners managed to get correct answers. Then they revisited the answers they gave in the pre-test and they were dissatisfied.

In the second stage of the conceptual change approach, which is intelligibility, the learners were given a chance to explore and find answers by themselves. This was achieved through experiments and filling in of worksheets. Two practical investigations were conducted, namely, relationship between acceleration and force and then, relationship between acceleration and mass. The learners were given all the apparatus and methodology to follow. When they had connected the apparatus and followed the method given, they recorded the values and tabulated the values. In the table the relationship between two quantities involved was clear and when comparing the physical quantities, they were able to arrive at the correct conclusion. This showed their understanding of the relationship between force, mass and acceleration.

The learners were also asked to use the information to draw graphs of acceleration vs force and acceleration vs mass using the information acquired through the experiment. The ability of learners to draw graphs showed the achievement of plausibility which is the third stage of the conceptual change approach. The learners were able to make sense of what they have learnt by interpreting it in the form of graphs. Once they understood the meaning of resultant force using a formula and stating it, they were ready to apply the knowledge gained in a totally different situation. The learners were also able to apply Newton’s second law of motion in real life situations, for example, speed of a car and how long will it take to control it when there is a need to stop it. The learners were able to solve calculations involving acceleration when a car is loaded and when it is empty as well as the distance it will take to stop. The last stage of conceptual change approach, which is fruitfulness, was achieved through this process.

5.4 WHAT WAS LEARNERS’ PERCEPTION OF THE CONCEPTUAL CHANGE APPROACH AS A TEACHING STRATEGY?

Focus group interviews were conducted for the purpose of triangulation. When the learners were asked why their marks were different, it was evident that the intervention had a positive effect on their performance in the post-test, since most of them got better marks compared to the pre-test.

The misconceptions held by learners during the pre-test were also shown even in interviews. Some of the learners could not define concepts correctly although they had an idea. Through probing and the guidance of the educator there were learners who managed to define concepts such as acceleration and resultant force correctly. When asked to apply Newton’s second law of motion, very few learners were able to do so. They came up with their own examples.

Then another interview question dealt with direct and inverse proportion of acceleration, mass and force. Learners could respond to this question and they stated that the experiments that they conducted helped them to understand this relationship perfectly. They were able to relate these physical quantities because they operated the apparatus themselves and recorded values and interpreted the results through drawing of graphs.

The learners were asked about their attitude towards Newton's second law of motion and they agreed that they were confident stating that the approach used to deliver the lesson helped them a lot. One learner felt that if practical investigations could be used to introduce each topic in physical sciences that could help them to make sense of what is taught and have a picture in their minds and this would facilitate learning and make it fruitful.

5.5 CONCLUSION

In this chapter the results obtained in the previous chapter were discussed. It was clear that the conceptual change approach is effective as the learners' performance improved drastically comparing the pre-test and the post-test.

Conclusions, implications and recommendations will be discussed in the next chapter.

CHAPTER 6

SUMMARY AND CONCLUSIONS

6.1 INTRODUCTION

In the previous chapter the results were discussed in detail. This chapter summarises the whole research and draws conclusions. The aim of this study was to determine the effectiveness of the conceptual change approach in teaching Newton's second law of motion to grade 11 learners.

6.2 OVERVIEW OF THE SCOPE OF THE THESIS

6.2.1 Introduction

In chapter 1 the background of the study was given. It has been discovered that very few scientists are produced by the country due to poor performance in physical sciences. The national, provincial and district state of science education was discussed. The results of physical sciences for grade 12 learners at provincial, district and school level were also presented (see sections 1.2 and 1.5). The interventions in science education in South Africa and in the Eastern Cape were mentioned too. The context where the research was conducted was explained. The environment where the study was conducted was defined. The research problem leading to the research questions was identified. The significance and the limitations of the study were discussed. An overall structure of thesis where the summary of all the chapters is given was discussed. The rationale of the study was provided justifying the need for conducting the research.

6.2.2 Literature review

Chapter 2 outlined the theoretical basis of the study. The study was based on constructivism and conceptual change theory. Robottom (2004) argues that learners use their own beliefs, interpretations and ideas to interpret information conveyed by teachers. Constructivism is therefore a major theory when working with conceptual change. According to Posner et al., conceptual change theory consists of four conditions, namely dissatisfaction, intelligibility, plausibility and fruitfulness. It is explained that when learners undergo these four conditions when an intervention is implemented, they tend to grasp subject matter easily. If the learner was dissatisfied with his/her prior conception and an available replacement conception was intelligible, plausible and fruitful, accommodation of the new concept may follow.

International and national literature explaining the scientific and alternative conceptions regarding Newton’s laws of motion was discussed. Different strategies on how to tackle difficult topics in physical sciences, for example mechanics – Newton’s second law of motion, were suggested (see section 2.3).

6.2.3 Research methodology

Chapter 3 provided the methodology for the research. The research design which was followed by the researcher in conducting the study was stated. A case study design using a mixed method approach was employed to address the research question. A quantitative and qualitative research technique was used. The research design included a case study, a pilot study and sampling. The data collection plan followed five steps which were pilot study, pre-test, intervention, post-test and focus group interviews.

Research instruments were also mentioned which include an interview schedule. An interview was conducted using an interview schedule and this was done for triangulation purposes. The method which was followed when the data collected was analysed was explained briefly. The practices which were followed to ensure validity and reliability were stated. Ethical considerations were explained and names of parties involved in the research were kept anonymous. Permission to conduct the study was requested from the companies involved.

6.2.4 Research findings

In chapter 4 the research findings were presented as corresponding to the research sub-questions**:**

6.2.4.1 *What was learners' initial understanding of Newton's second law of motion?*

The learners were given a pre-test and they performed very poorly as most of them failed the test (see Table 4 and Figure 1).

6.2.4.2 *How was the conceptual change approach implemented to teach Newton's second law of motion?*

The learners were exposed to an activity to make them realise that there were inconsistencies in their way of thinking which did not solve problems posed. This activity was designed in such a way as to address the misconceptions shown by learners in the pre-test. When the learners became dissatisfied with their answers, they were ready to accommodate the scientifically correct information.

The practical activities of *a vs m* and *a vs F* were given to the learners so that they could make sense of the relationship between acceleration, mass and force. The learners were also asked to draw graphs using the values recorded during the practical. The ability of learners to record and draw graphs showed that they had achieved intelligibility and plausibility. The learners were given classwork on Newton's second law of motion so that they could apply the knowledge gained during the practical. Real life situations were given to the learners so that the fruitfulness could be exercised.

6.2.5 Discussion

Chapter 5 presents a discussion of the major findings of the research corresponding to the data collected to answer the research sub-questions.

6.3 MAJOR FINDINGS OF THE STUDY

The following research question was used to identify the misconceptions and learners' understanding of the concept of the Newton's second law of motion:

How can teaching using a conceptual change approach improve the learners' achievement in Newton's laws of motion?

The data was collected according to the following sub-questions:

i) *What was learners' initial understanding of Newton's second law of motion?*

28 learners wrote the pre-test and more than half performed poorly. 58% of the learners scored less than 30%. This clearly showed that learners have misconceptions about Newton's laws of motion.

ii) *How was the conceptual change approach implemented to teach Newton's second law of motion?*

Intervention lesson was conducted involving different activities addressing the four conditions of conceptual change. The learners showed understanding of the lesson as they were actively involved.

iii) *What was the learners' understanding of Newton's second law after the conceptual change lessons?*

The performance of the learners in the post-test improved drastically. The number of learners who achieved 30% and under decreased from 15 to 9 learners.

iv) *What was learners' perception of the conceptual change approach as a teaching strategy?*

An interview, in the form of an interview schedule, was administered to the learners. The learners were divided into three groups, then numbered according to how many learners were in the focus group. The learners were probed to express their perceptions about the implementation of the conceptual change approach and understanding of Newton's second law of motion. It was clear from the learners' responses that their understanding of Newton's second law of motion had improved and that the conceptual change approach is an effective teaching strategy.

6.4 IMPLICATIONS OF THE STUDY

Conceptual change theory is a good teaching strategy. Effective conceptual change requires a great amount of effort from the teachers. For this reason, the experiential training of teachers is more than essential in order to achieve the long-pursued objective of the replacement of students' misconceptions with scientifically acceptable ones.

The research literature has shown that students come to their science classrooms with a range of different conceptions of the natural world surrounding them (Pfundt & Duit, 1991; Carmichael et al., 1990). These conceptions vary greatly with respect to such characteristics as clarity, breadth, coherence, ambiguity, and tenacity. In particular, many of these conceptions are at variance with the currently accepted scientific view. The significance of this research lies in the fact that these are the ideas that students use when they are introduced to normal scientific content. Thus, their learning of this new content is influenced by their current ideas in ways that may hinder or may help their learning. It therefore is useful to think of learning the desired outcomes as a process of conceptual change, including both extension and exchange. I believe it is the teacher's responsibility to be aware of students' conceptions and to teach in ways that are likely to facilitate conceptual change on the part of the students.

This study may be a guide to educators in terms of implementation of a learner-centred approach. Understanding of Newton's second law of motion in grade 11 enhances learners' understanding of Mechanics which is a topic in grade 12 physics in South Africa. This study can also be a guide in assessing the learners' physics conceptions because it showed that multiple-choice test items, open-ended test items and interviews were used for assessing learners' conception. Normally the aim of science education is to make all learners scientifically literate, and understand the basic science concepts and principles. The conceptual change approach can be implemented at schools to close the achievement gap among the learners at high school. Well-designed conceptual change texts can help lead to a significantly better acquisition of scientific concepts. Therefore, four conditions necessary for conceptual change mentioned by Posner et al. (1982) can be used while designing conceptual change texts. School managers should encourage teachers to use the conceptual change approach as a teaching method. Curriculum developers and educators should be aware that the conceptual change approach is an effective teaching strategy and can also be used in large sized classrooms.

6.5 LIMITATIONS OF THE STUDY

The research is a case study as it was conducted in one school only. The size of the sample is too small and is not representative of the whole sample. An extensive pilot test could not be done. The learners also had a language problem which made it sometimes difficult for them to understand what was being taught.

6.6 RECOMMENDATIONS FOR FUTURE RESEARCH

A number of schools can be used for the research to make it more reliable. Intervention can also be expanded to other topics in physical sciences so as to improve the performance of the learners in the subject as a whole. Even other grades can be exposed to the conceptual change approach as it has proven to be effective in teaching Newton's laws in grade 11. The sample could be expanded to a bigger population, that is, use a larger number of learners. A number of schools could also be used in the research, not only one school.

It is recommended that, when teaching Newton's second law of motion, the first activity the teacher has to do is to diagnose learners' alternative conceptions of related concepts (e.g. acceleration and velocity). The importance of the pre-test is to diagnose the existing knowledge of learners before introducing a new topic. This also provides guidelines and directives on how to plan and design effective teaching and learning experiences for learners.

Conceptual change is a complex process, and requires the proper environment and equipment. Therefore, the classrooms and/or laboratories must be equipped with the necessary materials and computer equipment.

6.7 Conclusion

This chapter provided a summary of the research and presented the essential components of this study. The application of the conceptual change framework as a teaching strategy proved that learners understanding of concepts can be enhanced but that not all learners achievements can be increased to the same extent.

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Appendix A

Pre-test and post-test Questions

QUESTION 1

1. The unit for measuring force is…

A kg B $kg.m.s^{-1}$ C $kg.m.s^{-2}$ D $m.s^{-2}$ (2)

2. Brian is driving a car at 16 $m{\cdot}s^{-1}$. He brings the car uniformly to rest in 4 seconds. The acceleration…

A $4m.s^{-2}$ B $-4m.s^{-2}$ C $4m.s^{-1}$ D $64m.s^{-2}$ (2)

3. An astronaut drops a hammer from 2 m above the surface of the Moon. If the acceleration due to gravity on the Moon is 1,62 $m{\cdot}s^{-2}$, how long will it take for the hammer to fall to the Moon's surface?

A. 0,62 s B. 1,6 s C. 1,2 s D. 2,5 s (2)

4. A rocket initially at rest on the ground lifts off vertically with a constant acceleration of 20 $m{\cdot}s^{-2}$. How long will it take the rocket to reach an altitude of $9,0 \times 10^{3}$ meter?

A. $3,0 \times 10^{1}$ s B. $4,5 \times 10^{2}$ s C. $4,3 \times 10^{1}$ s D. $9,0 \times 10^{2}$ s

(2)

Appendix B

LESSON PLAN

TEACHING METHOD/S USED IN THIS LESSON:

Question and answer

2. LESSON DEVELOPMENT

2.1 Introduction

A) PRE-KNOWLEDGE learners need understanding of the following:

(i) Distance, velocity and acceleration

(ii) Newton's second law definitions

(ii) Equations associated with Newton's second law

b) BASELINE ASSESSMENT (educator to design a worksheet/ transparency or write questions on the board [preferably a worksheet to save time] to gauge the learners memory of their relevant prior knowledge)

QUESTIONS for the **BASELINE ASSESSMENT [5 min]**

i) Define acceleration

ii) What is the relationship between resultant force and the acceleration of an object?

iii) Calculate the force required to accelerate a toy car of mass 2kg from rest to a velocity of 20 $m \cdot s^{-1}$ in 5 s.

Answers

(i) Acceleration is the rate of change of velocity

(ii) Resultant force is directly proportional to acceleration

(iii) $F_r = m\,\Delta v/\Delta t$

= 2(20-0)/5 = 8 N to the direction of motion20

Aim: To determine the mathematical relationship between force and acceleration when mass is kept constant.

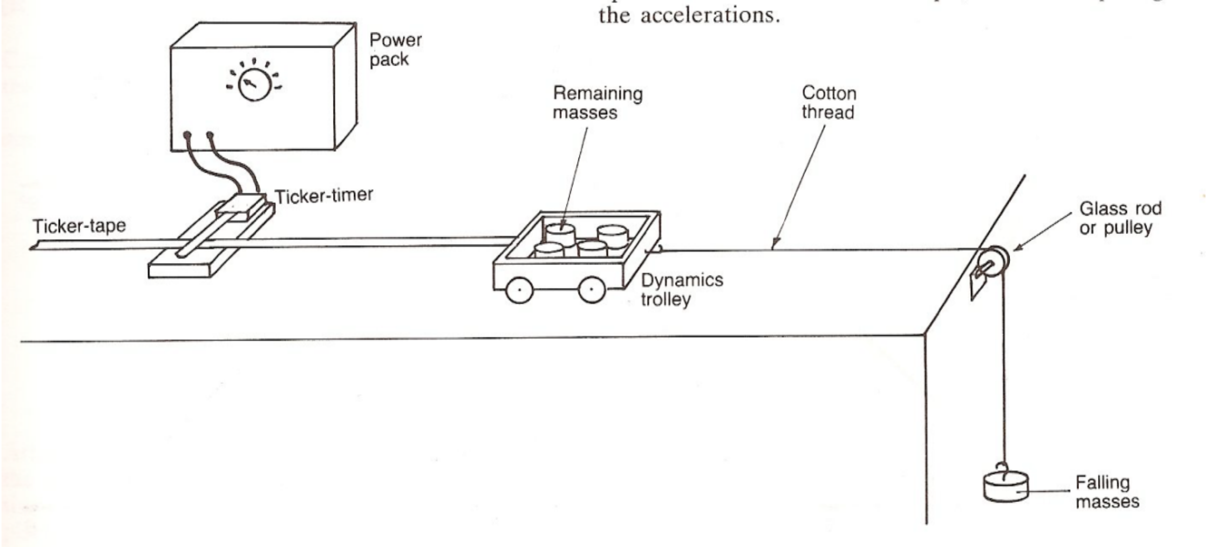
Apparatus: a trolley, variable mass pieces, pulley, clamp, string, plasticene, smooth table top/ trolley track, stopwatch or ticker-timer measuring tape

Variables: - Dependent variable

- **Independent variable**
- **Constant variable**

Diagram

up to the same time on each tape, we are comparing the accelerations.



Procedure

1. Connect the ticker-timer to the A.C. terminals of the power pack.
2. Attach a 60 cm length of ticker-tape to one end of the trolley and pass the tape through the ticker timer. Use plasticene to hold the timer in place.

3. To the other end of the trolley attach a length of cotton (enough to reach the floor). Attach the other end of the cotton to one of the masses.
4. Use the pulley (or glass rod held in place by plasticene) to provide a nearly frictionless surface for the cotton to run across at the edge of the bench.
5. The remaining four masses should be taped to the trolley so that they do not move or fall off.
6. Start the ticker-timer, release the trolley and allow the mass to fall to the ground. Discard any part of the tape produced after the mass has hit the ground. Label this tape 'Force 1'.
7. Transfer a mass from the trolley to the end of the cotton. Obtain a ticker-tape as in step 6 and label it 'Force 2'.
8. In a similar way obtain tapes for 'Force 3', 'Force 4', and 'Force 5' (with 3, 4, and 5 falling masses).

We assume that the acceleration is constant throughout the motion recorded on each tape. Hence distance travelled is given by

$x = v_i\, t + ½\, at^2$

For our tapes, $v_i = 0$ so $x= ½\, at^2$

If we choose the same initial time interval for each tape, then ***a α x.*** Hence by comparing the distances travelled from rest up to the same time on each tape, we are comparing their accelerations.

9. Begin your analysis with the tape 'Force 5'. Count the number of tick intervals from the first clear dot to near the end of the accelerating section. Measure the distance travelled in this time.

Results

10. Repeat step 9 for each of the other tapes using the initial section with the same number of tick intervals as above. Enter your results in a suitable table.

Appendix C

INTERVIEW SCHEDULE FOR LEARNERS

Subject: ………………. Date: ……………

INTERVIEW QUESTIONS

1.1 Are your responses in pre-test and post-test the same?

1.2 Give a reason for the above answer.

2. What is your understanding of the term ‘acceleration’?

3. Explain the term ‘resultant force’.

4. How can you explain direct proportion using Newton’s second law of motion?

5. Explain inverse proportion using Newton’s second law of motion

6.1 Would you be able to apply Newton’s second law of motion in real life situations?

6.2 Give an example of an application.

7.1 Do you find physical sciences interesting as a subject?

7.2 Why/why not?

8. How confident are you in solving problems dealing with Newton’s second law of motion?

Appendix D

OBSERVATION SCHEDULE

DIMENSION	INDICATORS	OCCURENCES(TALLY)	COMMENTS
Dissatisfaction	• Activity type used at the beginning of lesson (EXPOSING EVENT) • Learners participated actively, • Teacher-learner discussions (probing questions)		
Intelligibility	Learners observed, recorded, and were able to relate concepts in the form of graphs		
Plausibility	Interpretation and analysis done and conclusion drawn		
Fruitfulness	Learners extend their concepts and try to make connections between what they have learned and other situations		