

THE USE OF VISUAL REPRESENTATION AS A TEACHING STRATEGY IN THE PHYSICAL SCIENCE CLASSROOM

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DECLARATION

I declare that this research report is my own, unaided work. It is being submitted for the Degree of Master of Science in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

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17th August 2011

ABSTRACT

As science teachers, one of our objectives is to find new and effective teaching strategies to represent scientific concepts in a simplified and uncomplicated way to our learners. This study seeks to examine the merits of using visualisation as a means of representing science in a less complex way for learners as they come to terms with some of the conceptual difficulties that they experience.

One of the challenges this study aims to highlight is the multilingual environment that physical sciences educators must teach within where learners experience conceptual difficulties as well as learning difficulties as a result of language. This study is set against the backdrop of a typical South African township school where learners learn science in a second language. A sample of 31 learners and their science teacher participated in the research.

The use of a visual representation in the form of a series of pictures representing various scenarios of objects colliding was used by the teacher to consolidate the learner's existing knowledge of the concept of conservation of linear momentum. The results obtained from the questionnaires and interviews indicate that the majority of the learners could have benefitted from the pictures. The pictures served as a means of remediating some of the conceptual difficulties that they had experienced in relation to the vector nature of the motion of the colliding objects, in particular.

The study could not conclusively ascertain whether the use of visual representation can specifically help second language learners in overcoming their learning difficulties as a result of the language of instruction. Despite this outcome, the results of the study did indicate that the learners had benefitted from the visual representations. Some of the learners had expressed that the pictures had visually brought to life the practical scenarios that they would have otherwise experienced only through the verbal and written mode of instruction.

The study recommends that visualisation in science education can play a significant role in helping learners with conceptual difficulties not just as a result of the language of instruction but also as a result of the general complexities of science that are abstract to even first language learners.

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CHAPTER ONE - INTRODUCTION

1.1 General introduction

Like most third world countries, South Africans have also experienced the effects of globalisation and therefore find themselves competing in a modern world where economic growth is strongly related to scientific and technological development. In an effort to keep adrift with global trends, numerous educational reforms have taken place in our country that aim to emphasize the importance of science education in creating a more scientifically literate society. The need to promote science and encourage our learners to pursue a career in science has become part of a range of challenges that face science education worldwide (Gilbert, 2004).

The challenge of promoting science in our schools is formidable and is necessitated by the fact that learners at school level are often discouraged by the abstract learning content and the complexity of problem solving that is associated with physical science. The learning content is difficult to interpret at times due to the theory laden science curriculum which sometimes does not adequately represent phenomena of the real everyday world that we experience; hence this can lead to a lack of interest in science amongst learners (Gilbert, 2004). There are numerous examples of learning content that can be deemed as being difficult for learners to comprehend hence this study focused on one such learning content namely the conservation of linear momentum.

The conservation of linear momentum forms part of the mechanics module that is currently being taught to grade 11 and 12 physical science learners in South African schools. This learning content was chosen for this study since it was found, through my experience, that learners encounter many learning difficulties in relation to the vector nature of linear momentum despite the concept of direction being an everyday phenomenon (Bryce & MacMillan, 2009).

The learner's inability to correctly predict the direction of the motion of two colliding objects is a very common feature that has been noted during my classroom experiences. This is especially prevalent during problem solving exercises, where learners fail to take direction into account when substituting numerical values for velocity into the conservation of linear

momentum equation. When they do make correct substitutions, another problem is that learners find it difficult to manipulate the equation in order to solve for the unknown value. Changing the subject of the formula and solving for the unknown value is a difficulty that learners experience not only in conservation of linear momentum but also in other aspects of physical science especially where problem solving is involved.

These difficulties experienced can be frustrating for the learners and can affect the learner's attitude towards science (Osborne, Simons & Collins, 2003). Learners become disillusioned when they are experiencing learning problems and can develop a negative attitude. A negative attitude towards science can lead to a lack of motivation and self belief and the learners will ultimately perform poorly in science (Mji & Makgato, 2006; Osborne, Simons & Collins, 2003). The lack of conceptual understanding can be one source for this type of attitude and would affect the learner's performance negatively.

Our task as teachers is to help learners to attain a better conceptual understanding of the complex learning content such as conservation of linear momentum in order to develop positive attitudes in our learners. According to Osborne et al (2003), a positive attitude towards science means that the learners generally enjoy studying science and are committed and motivated to achieve in the subject.

Science teachers can effect change in both the learner's attitude and their performance in science through their teaching strategies. Part of the problem lies with the science teacher who, in some cases, is unable to adequately transform the theory laden science curriculum into a user friendly format that relates to the real everyday world that we live in (Gilbert, 2004). To achieve this objective the teacher's pedagogical competency and a certain level of creativity is needed to employ different teaching strategies in the classroom. This can help to minimize the challenge of translating intangible learning content into simpler form to the learners.

These different teaching strategies need to ensure that the science curriculum is made more authentic and accurately captures the colourful, visual and dynamic world of science during classroom discourse (Gilbert, 2004). To this end, this study has investigated a teaching strategy that makes use of visualisation during the teaching of the conservation of linear momentum. A visual representation in the form of a set of pictures that visually depict the

sequence of events taking place between two objects before and after collision was given to the teacher participant to use during his lesson which formed part of this study. The intention was to determine whether the introduction of visual representation had minimized some of the learning difficulties that the learners had experienced and promoted better conceptual understanding amongst the learners.

The objective of this study was to promote visualisation and more specifically, the use of visual representation as a teaching strategy, which is well placed to address the lack of conceptual understanding leading to learners performing poorly in science in South Africa.

1.2 Background/Rationale

Much research has been done regarding why learners perform poorly in mathematics and science. Factors that have been found to have a significant influence on learner performance includes the lack of resources in the form of laboratory equipment and textbooks, the lack of adequately qualified teachers, teachers lacking proper knowledge of teaching strategies and the challenge of learning and teaching in a language of instruction that is not the first for most learners and teachers (Howie, 2003; Mji & Makgato, 2006). Poor results are especially prevalent in schools where the majority of learners are second language learners. In South Africa, it also happens that such schools have been previously disadvantaged in terms of resources and the learners also come from disadvantaged backgrounds.

In Howie's research into how language affects learner performance, results indicate a positive correlation between language proficiency and learner performance. Second language learners are likely to perform poorly in science as a result of their low proficiency level in English especially if it is the language of instruction (Howie, 2003). Poor language proficiency in the classroom language of instruction as a result of home languages not being adequately used had contributed to the learners' poor results. Her conclusions were based on her analysis of a sample of South African learners who participated in the Third International Mathematics and Science Study (TIMSS).

In comparison to some of the other countries that participated, South Africa was the worst performing country yet there were other countries such as Indonesia and Malaysia who did not appear to be "disadvantaged by writing the test in a second language" (Howie, 2003, p.

7). One can assume that other underlying factors such as, the availability of resources, class sizes and the quality of teachers; have also contributed to the poor maths and science results (Howie, 2005). Despite these factors, language proficiency is still seen by researchers to have the most influence on the learners' performance (Howie, 2003).

The question would therefore arise as to whether the attainment of a particular level of language proficiency in the language of instruction is the only prerequisite for performing better in science (Oyoo, 2007). In his paper, Oyoo explains that conceptual understanding of science is not just restricted to second language learners since first language learners also experience conceptual difficulty. Hence there are general difficulties that are associated with scientific conception. These difficulties are linked more to the technical component (scientific terminology and science laws) compared to the non technical component (classroom language) of language usage (Oyoo, 2007).

One can refer to the technical component as the actual scientific language that a learner needs to have, in order to become scientifically literate. Therefore, if the current status quo of learning science in English is a generally accepted principle in South Africa, second language learners are at a disadvantage in terms of having to focus on both the technical and the non technical aspects of language usage as they learn science. In other words, the learning of abstract scientific concepts coupled with the challenge of learning in a second language would ultimately have a negative bearing on the learner's performance in mathematics and science (Rollnick, 2000).

In order to address this challenge, Howie suggests that an effective method would be to use representations in the form of pictures and symbols to help with the learning process (Howie, 2003). Rollnick also makes mention of "using various semiotic tools, such as diagrams" which would be "particularly useful for second language learners" (Rollnick, 2000, p. 112). Mammino proposes the use of visual strategies as a means of addressing learning difficulties experienced in science by learners as a result of "the use of second language as a medium of instruction", "inadequate familiarity with science" and "inadequate visual literacy", (Mammino, 2008, p. 160).

Such strategies may be beneficial not just to second language but also to first language learners in terms of attaining better conceptual understanding of science; hence the focus of

this research report is on the use of visual representation as a strategy during the teaching of science.

Although not being a current focus in science education, the use of visual representations such as pictures, diagrams and models can be seen as an important teaching and learning strategy for second language learners. As an emergent field, the use of more visual representations during classroom discourse may help to improve conceptual understanding resulting from poor language proficiency for example.

The use of diagrams, models, pictures and graphs are not necessarily new concepts since teachers have always used these strategies. However one needs to examine whether they are used effectively and consciously. In the context of second language learners, these representations can be used in simplifying difficult science concepts making it easier to understand.

From my experience as a science teacher, it has been noted that conceptualisation of scientific content can be made easier if learners are able to visualise the concept and relate it to an everyday occurrence. Diagrams, models and practical experimentation in the laboratory, can be effective in helping learners to visualise and create mental pictures of concepts (Gilbert, 2004). As teachers our task of successfully implementing these visual strategies in our teaching can be challenging since one has to look at whether there are media resources that are available for a teacher to utilise especially in rural areas and urban townships schools where there are second language learners. Another challenge lies in the level of the teachers' pedagogical content knowledge in terms of whether they have the expertise in creatively utilising visual representations in their teaching. How to counter some of these challenges were investigated through this study.

1.3 Aim of Study

The aim of the research project was to determine whether a teaching strategy that incorporates visual learning would help in promoting better conceptual understanding in physical science. This aim was investigated through the following specific research questions.

1. Does the use of visual representation in the form of pictures and photographs, help to promote better conceptual understanding in physical science?
2. How do these visualisation strategies help second language learners in bridging the gap in conceptual understanding due to language difficulties?

The answers to these questions form the basis of the research report.

1.4 Chapter Summary

This chapter introduced the study that was conducted. It was identified that learners perform poorly in science and more specifically in the topic of conservation of linear momentum as a result of poor conceptual understanding. Other contextual factors such as the lack of educational resources and the language of instruction had been mentioned as other reasons for the learner's poor performance. English language proficiency had been singled out to have the most impact on the learner's performance in South Africa. As a means of promoting more effective teaching strategies to address the above issues, the study proposed the use of visualisation in science education. The use of visual representation in the teaching of conservation of linear momentum was suggested as a means of helping learners to reconcile some of the learning difficulties as well as to address the issue of language of instruction. In terms of the structure, the rest of this research report is structured as follows: Chapter two provides a summary of the literature that was reviewed for the study. In particular it has reviews on the learning difficulties experienced by learners in the conservation of linear momentum and visualisation as a teaching strategy. Chapter three details the research approach adopted and the research methods that were used to collect the data. Chapter four provides insight into the research context, selection of the research participants, research site as well as the planning for and actual collection of data. Chapter five focuses on the results obtained from the data and the analysis of these. Finally, in chapter six, the results are discussed in terms of the research questions. Implications and recommendations are made in relation to the outcome of the study.

CHAPTER TWO - LITERATURE REVIEW

2.1 Introduction

In this chapter, literature with regard to the use of visualisation in science education with the specific aim of addressing learning problems that can be encountered during the study of conservation of linear momentum has been presented. Reviews of the conceptual difficulties relating to conservation of linear momentum are first presented followed by the review of use of visualisation in science teaching.

2.2 Learning difficulties in relation to conservation of momentum

As science educators, one of our tasks is to address conceptual difficulties that learners may experience during the learning of science. When learners are confronted with learning content such as the conservation of linear momentum, there are numerous learning difficulties that are encountered. There is very little literature available on conceptual difficulties experienced with respect to linear momentum especially in terms of numerical problem solving and use of the conservation equation (Bryce & MacMillan, 2009). During the use of the conservation equation it is found that learners are often unable to relate to the “algebraic formalism” of numerical problem solving (Grimellini-Tomasini, Pecori-Balandi, Pacca & Vallani, 1993, p. 171). Problem solving is also viewed as being a “mechanistic, number crunching approach” that is usually unprofitable to promoting conceptual understanding (Bryce & MacMillan, 2009, p. 739).

The gaining of competency in problem solving does not necessarily mean that the learner has understood the concepts. Part of the problem lies in the learner’s motives in terms of how the learner views science, which is very different to the views expressed by teachers. According to Villani (1992), the teacher’s general objectives differ vastly from the learner’s objectives in that the learners rationalise the academic activities that they engage in as a means to an end rather than a means of becoming highly efficient in problem solving at an intellectual level. In other words, they view classroom activities as a means of assisting them to achieve their objective of passing their exams rather than focusing on actual scientific principles behind their actions (Villani, 1992).

Learner's objectives are different from that of the teacher's since their means to an end approach allows for them to employ reasoning that is usually spontaneous when it comes to problem solving activities (Villani, 1992). They use common sense knowledge instead of general scientific theories and principles that would be used by a scientist (Villani, 1992). For example, when an object falls through the air, learners use spontaneous reasoning to explain that the object's motion is as a result of the object's mass (weight) rather than the using Newton's third law to explain that the earth is attracting the object. In terms of conservation of linear momentum for example, when an object collides with another object, learners often focus on the action of the first object and its effect on the target object rather than focusing on the initial, intermediate and the final states of the objects (Villani, 1992).

This example is further observed in collision experiments where it is found that learners generally only focus on trying to make the one trolley hit the other and do not focus on the collision itself or what happens to the trolley after the collision (Grimellini-Tomasini et al, 1993). It was expressed that learners who use spontaneous reasoning as opposed to disciplinary reasoning to interpret the conservation law of momentum would often predict that objects do not moves backwards and only moves forward if its mass is larger than or equal to the target object; it will stop if the mass is smaller than the target object (Grimellini-Tomasini et al, 1993).

These conceptual difficulties can also occur due to the learner's prior knowledge. For example, literature shows that in collision studies learners often do not understand the concept of how forces have an impact on the actual collisions of objects (Grimellini-Tomasini et al, 1993). From my teaching experience it has also been observed that learners have the misconception that the larger mass will exert a greater force on the smaller mass as the two objects of different masses are colliding with each other. Learners are therefore not in a position to understand how momentum can be conserved if objects are exerting different forces. This lack of conceptual understanding is in relation to the learner's prior knowledge of Newton's third law (Bryce & MacMillan, 2009; Grimellini-Tomasini et al, 1993). Learners have difficulty in accepting that the forces exerted by the masses are of equal magnitude.

Besides the effect of forces, learners also do not appreciate the difference in the terms velocity and momentum since the velocity is not conserved during collisions while

momentum is always conserved, “even though they find it necessary to describe collisions in terms of the product of mass and velocity (mv) to take into account the role of the different masses” (Grimellini-Tomasini et al, 1993, p. 174)

The vector nature that is associated with problem solving is also seen as a common learning difficulty that learners experience (Bryce & MacMillan, 2009; Graham & Berry, 1996; Grimellini-Tomasini et al, 1993). The inability to take into account the direction of the moving projectiles within a problem solving context is often experienced and has a bearing on the calculated momentum values. Although learners recognise momentum as a vector quantity, during problem solving, they tend to look at it from a scalar perspective and interpret this concept in terms of the product of mass and speed instead of mass and velocity and this inevitably affects the outcome (Graham & Berry, 1996).

Another learning difficulty that has been highlighted is the learner’s inability to distinguish between elastic and inelastic collisions. During a collision, mass is conserved since the force only changes the velocity unless it is an inelastic collision then the mass changes as a result of the crumpling effect and energy is lost (Bryce & MacMillan, 2009). The other aspect is their inability to understand that energy may be lost during an inelastic collision however momentum is still conserved.

Learner difficulties in the conservation of linear momentum may be attributed to the current prevailing teaching pedagogy. According to Bryce and Macmillan (2009), the current teaching strategies might be the source of all the misunderstandings. In relation to the conservation of momentum, the general pedagogy focuses on mainly drilling the learners into problem solving and the rules associated with it rather than helping to understand the conceptual difficulties of the learners. Pedagogy is directed towards simply getting learners to rearrange the formulae and substitute values in an attempt to obtain the “right answer” (Bryce & MacMillan, 2009, p. 753). This type of approach does not allow for learners to become deep thinkers and critical about interpreting and predicting real life practical situations. Teaching strategies must into account both a spontaneous approach and an academic approach to decision making during problem solving activities (Grimellini-Tomasini et al, 1993; Vallani, 1992).

Teaching strategies need to ensure that scientific concepts are expressed explicitly as possible (Vallani, 1992). In order to achieve this, scientific representations must be made as realistic as possible. This study made use of visual representation as a means of representing conservation of linear momentum with the objective of addressing some of the conceptual difficulties experienced by the learner participants. Hence the focus of the literature review now shifts to visualisation.

2.3 Visualisation as a teaching strategy

The use of visualisation in the teaching of science has become an important area of study in recent years ever since it was pioneered by researchers such as Gilbert (2004, 2007, 2008), Coll & Treagust (2001). Their work in this emergent field has gained the attention of science practitioners, whom in the quest to create scientific literacy amongst learners are always searching for new approaches to teaching. Since their work has provided valuable insight into how the process of visualisation influences the learning of science, they feature prominently in the majority of the literature that was reviewed for this research report.

Visualisation is seen to play a significant role in science education since it highlights the cognitive processes that are associated with how learners can successfully interpret scientific phenomena (Briggs & Bodner, 2007; Gilbert, 2007; Gobert, 2007; Rapp, 2007; Tversky, 2007). This cognitive process which involves the learning of science and applying this knowledge can usually be very daunting for the learner since science can be very complicated at times due to the abstract nature of some of the concepts that are encountered. Science educators are faced with the task of simplifying these complex scientific phenomena into forms or representations that the learners would be able to comprehend cognitively.

The comprehension of scientific concepts and principles in a meaningful way essentially relates to how well the learners can critically think about the concepts that are presented to them (Rapp, 2007). This is dependent on how learners cognitively incorporate the information into their memory and how it can be retrieved and applied at any given time. If the learner has achieved these levels of deep sense of thinking, one can then assume that the learner has reached conceptual understanding. Hence the conceptualisation of science itself is a cognitive process and visualisation is seen as one such cognitive tool that can be utilised

as a means of communicating scientific concepts in a meaningful way to the learners (Tversky, 2007).

From the perspective of being a cognitive tool, visualisation in science can be defined as a mental activity that takes place as the learner tries to correctly comprehend new scientific concepts that is presented to him (Rapp, 2007). Visualisation is regarded as an important metacognitive tool that learners can use in order to successfully understand scientific concepts (Gilbert, 2008). Learners must try to view science as small parts or “chunks” rather than as a continuous process; in this way learners are in a position to develop cognitive mental models of scientific phenomena. Therefore if one has to define the term visualisation, it would mean using the mind to visualise scientific phenomena and create mental pictures or “internal representations” (Gilbert, 2008; Rundgren & Tibell, 2009). These internal representations are mental constructs that would form part of the learner’s knowledge base and can be used in other learning situations.

Through the science teaching that takes place in the classroom, learners are exposed to new scientific phenomenon on a daily basis. In order to successfully interpreting new concepts, learners have to internalize new knowledge by creating mental pictures. Mental pictures are visual images of concepts that learners form in their minds that would help them to recall this information when required. Many researchers attribute the successful facilitation of this mental processing of information to the use of mental models (Coll & Treagust, 2001; Gilbert, 2007; 2008; Rapp, 2007).

2.3.1 Mental Models

Mental models are essentially internal representations of how the learners perceive certain scientific phenomena (Coll & Treagust, 2001; Greca & Moreira, 2000). These internal representations are created through our interactions and experiences with the external world hence mental models are created as a result of the combination of one’s existing stored knowledge with one’s immediate experiences (Greca & Moreira, 2000, Rapp, 2007). As learners start to develop a mental model of concepts, they are in a position to use this to be able to reason, perform problem solving activities and make logical deductions about scientific phenomena.

As individuals, we may perceive scientific phenomena in different ways and may have different internal representations, for example during the learning of electric circuits, learners commonly develop a mental picture of an electric circuit as a complex system of pipes through which water is flowing, or some view it in terms of cars and traffic flowing through a sequence of roads as a means of interpreting current flowing through conductors in a circuit (Engelhardt & Beichner, 2004). With regards to conservation of linear momentum, many learners view this concept in terms of two colliding billiard balls (Bryce & MacMillan, 2009). These mental models are very personal and unique to the individual since the learner would usually relate it to some of their own personal experiences. Based upon their individually constructed mental models, learners would therefore interact differently with scientific concepts and find different pathways to solving problems. This may be problematic especially if learners develop incorrect mental models (Briggs & Bodner, 2007).

If a learner incorrectly interprets a concept in the science classroom it can usually lead to confusion resulting in the learner constructing an incomplete or improper mental perception. Therefore incorrect or inaccurate mental models can result when the learner has not completely comprehended the concepts that are being taught in the classroom. Researchers often view this as a source of the many misconceptions and misinterpretations experienced in science (Briggs & Bodner, 2007; Coll & Treagust, 2001; Rapp, 2007). Misconceptions as a consequence of incorrect mental models, is mainly prevalent in novices who usually lack the abilities of the expert scientist in terms of successfully differentiating and interpreting concepts (Coll & Treagust, 2001).

Inaccurate mental models and misconceptions are common in science since the abstract nature and complexities associated with some of the concepts that are taught to the learners tend to sometimes inevitably lead to poor conceptual understanding in some of the learners (Greca & Moreira, 2000). As in the case of conservation of linear momentum where many conceptual difficulties have been highlighted above (refer to Section 2.2), one can therefore assume that some of these learning difficulties are as a result of inaccurate mental models that the learners have created.

The task of changing these mental models and addressing the misconceptions can be difficult and lies mainly with the science teacher whose responsibility in the first place is to ensure that science is taught in a manner that accurately and simplistically translates these

complex concepts so that the learning process is uncomplicated. Therefore the nature of the cognitive processes involved in constructing proper and accurate mental models can be made less complex depending on how science teachers are able to externally represent science to their learners (Greca & Moreira, 2000). Hence visualisation in science education does not only rely on the internal representation by the learners but also on external representation in terms of how science is presented to the learners (Gilbert, 2008).

2.3.2 External Representations

Much has been written about how scientific theory can be accurately translated into external representations that can help learners to bridge the gap between theory and the real world (Gilbert, 2004, 2008; Greca & Moreira, 2000). According to Gilbert, there are five representational modes that can be used to translate scientific concepts into a simpler form for learning.

The *concrete mode* is characterised by the use of physical materials to demonstrate scientific concepts. The *verbal mode* relates to the teacher using a series of metaphors and analogies in their explanations of scientific concepts. The *symbolic mode* relates to mathematical expressions and equations that are used to explain concepts. The *visual mode* encompasses diagrams, graphs and animations as useful representations for explaining abstract phenomena. The *gestural mode* emphasizes the use of hand and certain body movements that teachers use in order to demonstrate concepts to their learners (Gilbert, 2007). All five of these representational modes require the learners to use visualisation as a means of learning science.

External representation as a visual mode can be expressed in terms of three levels, namely the microscopic, macroscopic and symbolic level (Gilbert, 2004, 2008; Wu, Krajcik & Soloway, 2001). The macroscopic level relates to what the learners are physically seeing and engaging with during the learning process. Scientific concepts are interpreted purely through sensory experiences (Wu, Krajcik & Soloway, 2001). At macroscopic level, one can think of numerous examples that relate to all spheres of science. In terms of physics, the observation of motion influenced by forces in the conservation of linear momentum, the viewing of diffraction patterns in water waves using a stroboscope, the observation of attractive and

repulsive forces between charged objects and the observation of the spectral colours of white light are some useful examples of the macroscopic level.

Representations at a microscopic level are those entities that would not necessarily be observed by the naked eye. In physics the movement of current through a conductor or, the movement of electromagnetic waves through air, are scientific phenomena that can be regarded as microscopic. In chemistry, a common synonym used for microscopic is “molecular” (Tasker & Dalton, 2006). To quote examples of microscopic levels in chemistry would be too vast as the very essence of chemistry is based on tiny invisible particles such as atoms, ions and molecules.

Representations at a symbolic level are the most abstract from all three representations since they arise out of entities related to the microscopic representations, except that they are in “Shorthand” (Gilbert, 2008, p. 4). Symbolic representations can therefore be seen to mimic microscopic representations although in a much more condensed form. Symbolic representations are used more widely in chemistry since chemical reactions at a microscopic level can easily be represented through symbolic representations as chemical equations. In chemistry, Tasker and Dalton expressed that the symbolic level can be explained qualitatively by using “specialized notation, language, diagrams and symbolism” while mathematical interpretations can be used to describe it from a quantitative perspective (Tasker & Dalton, 2006). In physics a variety of symbolic representations are used as well. Symbols such as lambda (λ) and omega (Ω) are used to represent wavelength and the unit of measuring resistance respectively. Symbolic representation in physics is used mainly in the form of mathematical expressions and equations in areas such as mechanics, waves and electricity.

My experiences in the classroom has indicated that external representation through symbols at a microscopic level poses the greatest problem for many learners and teachers especially in learning content such as mechanics and electricity. Learning content that relates to the microscopic and symbolic level can be difficult to interpret since learners cannot physically visualise what is happening at these levels (Tasker & Dalton, 2006). This is often the source for conceptual difficulty in learners. In the conservation of momentum, the translation of the physical changes that two objects undergo during and after collision (at a macroscopic level) into symbolic representation is part of the learning difficulties that learners encounter (Graham & Berry, 1996).

The symbol notation of the equation $m_1v_{1i} + m_2v_{2i} = m_1v_{1f} + m_2v_{2f}$ ¹ has been highlighted in section 2.2 as a source of difficulty in relation to learners performing problem solving activities.

As pointed out earlier, for teachers, the challenge lies in being able to devise teaching strategies that would help learners to visualise better at these levels. Researchers have provided a variety of visual tools and multiple visual representations that teachers have utilised as a means of successfully translating concepts at the macroscopic and the sub-microscopic level (Gilbert, 2008). Once again, the central focus of these discussions, are based on the use of mental models and models in general as visual tools. The cognitive process that involves the use of visual tools such as models in helping learners to develop a more accurate understanding of scientific concepts formed the basis or theoretical framework of the particular study reported in this research report, therefore one needs to explore the concept of models in greater detail.

2.4 Models and Metavisualisation

Models can be regarded as “simplifications” that can be used to assist learners in their “visual perceptions” of scientific phenomena at the microscopic level (Gilbert, 2007, p. 10). A model can be used to simplify many concepts in science since they are visual in form and can be seen as a representation of reality hence models serve as a link between “theory and reality” (Koponen, 2007, p. 766). Some of the complex and abstract scientific theory can be visually transformed into everyday examples and therefore models are useful in communicating scientific concepts to the learners. The development and use of models in science education has become an important element in the construction and sharing of scientific knowledge (Gilbert, 2007; Koponen, 2007; Matthews, 2007).

Models can represent a variety of entities in science ranging from physical material objects to abstract representations (Coll & Treagust, 2001). Physical objects are concrete, real objects that are used in physics to demonstrate scientific theory, for example swinging weights hanging from a string can be used to demonstrate simple harmonic motion

¹ Conservation of linear momentum equation represented by the sum of the product of the first mass and its initial velocity and the second mass and its initial velocity is equal to the sum of the product of the first mass and its final velocity and the second mass and its final velocity.

(Matthews, 2007). The use of two trolleys connected to a ticker timer on a runway or the use of two trolleys and an air track is useful in demonstrating conservation of linear momentum. Such examples are referred to as physical models.

In terms of abstract representations, models are expressed mainly in the form of diagrams (Coll & Treagust, 2001). These diagrammatic representations can be in three dimensions or in two dimensions. At a microscopic level in chemistry, many teachers use two dimensional diagrams to demonstrate molecular bonding models such as the ball and stick model as well as the space filling model (Coll & Treagust, 2001). In Physics the use of two dimensional diagrams are used by teachers to represent force diagrams on objects such as mass trolleys (Buffler, Lubben, Bashirah & Pillay, 2008; Heckler, 2009). These models for abstract representation are referred to as conceptual models (Buffler, Lubben, Bashirah & Pillay, 2008; Coll & Treagust, 2001). Conceptual models are external representations that are created by the teacher to simplify the learning (Greca & Moreira, 2000).

Conceptual models together with physical models are broad categories which form part of mental models (Coll & Treagust, 2001). As mentioned earlier (refer to Section 2.3.1), mental models are developed on an individual basis during the learning process. As learners are exposed to a range of external representations, they personalise and internalise these representations by developing mental models (Greca & Moreira, 2000). During the process of forming mental models, a metacognitive learner would be constantly thinking about his own learning in terms of how to improve on the learning process and his understanding of science. Visualisation is seen as a means of helping learners to achieve a level of metacognition where learners are able to create competent mental models and become more effective in their conceptual understanding. Gilbert coined the term metavisualisation as a result of this close link between visualisation and metacognition (Gilbert, 2007).

Three sources of evidence were provided to support the concept of metavisualisation. Firstly the fact the individuals have general spatial intelligence means that they are able to visualise and understand objects from a three dimensional and two dimensional perspective (Gilbert, 2004). Secondly, there is a general model for the operation of memory in which learners utilise metavisualisation in producing a visual image of what is being learnt in the classroom. The learner's visual perception of the concept that is being learnt is initially attained at the meta-level of the brain after which it is stored and retrieved by the learner

(Gilbert, 2007). Thirdly, visualisation forms an integral part of one's thinking process. The ability of an individual to reason, learn new skills, comprehend verbal descriptions and become creative is as a result of individuals being able to visually perceive concepts and establish a "visual memory" of concepts (Gilbert, 2007, p. 17). Based on these sources, visualisation is therefore viewed as playing an important role during the learning of science.

Since visualisation is seen as an important component to learning, one can assume that if a learner is struggling with his understanding of a particular scientific concept, this could be as a direct consequence of a poor metavisualisation. For example the difficulty that learners have in translating examples of collision in conservation of linear momentum into symbol notation for calculation purposes can be as a result of poor metavisualisation. In chemistry, for example, it was highlighted by Kosma and Russel (1997) that learners experience difficulty in understanding chemical representations at a microscopic and symbolic level. This lack of understanding can be attributed to the learner's lack of metavisual skills. A metavisual skill such as having the ability to spatially distinguish concepts at the microscopic and symbolic level is only developed during the actual learning process, for example, Kosma and Russel (1997) advocates the use of multimedia and multiple representations as a means of developing skills associated with visualisation and science.

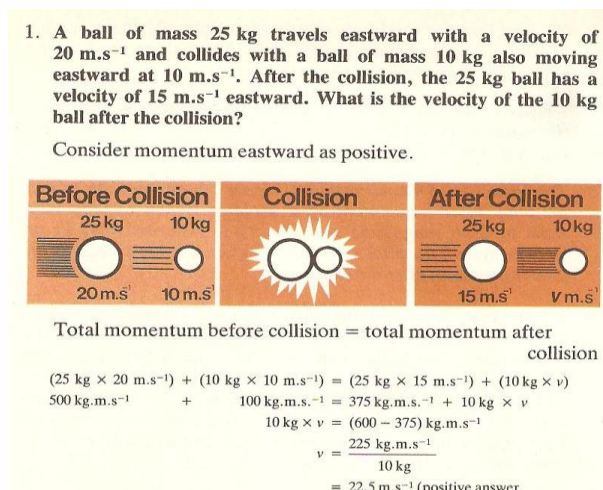
The use of multimedia and multiple representations that have been used in recent times have a positive impact on the learning process in terms of enhancing metavisualisation skills in learners (Gilbert, 2007). Gilbert further argues that multiple external representations of science have proven effective in helping learners to visualise concepts hence resulting in a higher level of conceptual understanding (2007). Some of these multiple representations that are used frequently include models, diagrams, photographs, graphs, animations, analogies and in more recent times the use of virtual representations are becoming very popular (Trunfio, Berenfeld, Kreikemeier, Moran & Moodley, 2003).

2.5 Diagrams

Diagrams are the most common and probably the oldest form of representation that have been used in communicating scientific phenomena. Most scientific textbooks contain rich arrays of diagrams that are seen to play a supportive role to learners successfully interpreting scientific concepts. Science makes use of a variety of diagrammatic forms ranging from

pictorial diagrams to the more abstract line drawing diagrams (Gilbert, 2008). Pictorial diagrams are probably the easiest to interpret since they appear to be more simple and uncomplicated. An example of a typical pictorial diagram that is used to depict two colliding objects during the conservation of linear momentum is represented in the figure 1 below:

Figure 1: Pictorial diagram used in conservation of linear momentum (Brink & Jones, 1995, p.44)



The visual impact of pictorial diagrams and pictures has been known to have a positive effect on learning and helps learners to cope better with problem solving (Mualem & Eylon, 2010). This was articulated in Mualem & Eylon's study in which visually rich diagrams were used in the learner's questionnaire to express real life problem solving scenarios. These visual representations were then required to be interpreted from a free body diagram perspective in respect to problem solving. The results indicated that the learners had benefitted from the strategy of using visual representations.

From my experience as a physical science teacher, I have found that the use of these visual representations is very effective in promoting better understanding of concepts. The following two pictorial diagrams/pictures below (see figure 2 & 3) are examples of what I have used during my teaching experience. Figure 2 illustrates the pain of impact experienced by a cricketer trying to catch a ball when he disobeys the law of momentum and impulse (Brink & Jones, 1995, p. 37). In figure 3, the picture represents an analogy relating to the concept of dynamic chemical equilibrium in relation to the forward and reverse reaction (Olivier, 2009, p.160).

Figure 2: Application of momentum-impulse



Figure 3: Dynamic equilibrium



Abstract line drawing diagrams are more complex than pictorial diagrams. The introduction of labeling and the use of arrows to indicate various components are frequently used in abstract diagrams relating to the field of life sciences. The intensive use of labels and arrows in diagrams are seen as a means of increasing the visual value of the diagram (Gilbert, 2008). In a study conducted by Rundgren and Tibell (2009) regarding how visual representation, in the form of diagrams and animations can be used as visual tools in helping learners to learn concepts in molecular life science, they concluded that the use of diagrams helped not just in terms of visual value but also in terms of addressing student difficulties and misconceptions.

In physics abstract diagrams are often used as a means of representing real situations within a problem solving context. At this abstract level, the use of vector diagrams and free body diagrams are commonly used in physics to simplify concepts to the learners. Researchers have found that problem solving in physics can be made easier by representing the abstract variables in a diagram form (Heckler, 2009; Mualem & Eylon, 2010). During his experimental work, Heckler found that the use of force diagrams and free body diagrams had greatly assisted his physics students in achieving better conceptual understanding in problem solving that is associated with mechanics (Heckler, 2009).

In another study conducted by Graham and Berry into the development of student understanding of momentum, they expressed that the “geometric” approach should be used more than the “algebraic” approach during problem solving especially in two dimensional momentum since it may lead to improved conceptual understanding (Graham & Berry, 1996, p. 85). The geometric approach essentially refers to the use of diagrams to represent the colliding object’s motion with respect to the x and y directions.

The literature presented indicated that there are merits in using diagrams and pictures as visual representations in the physical science classroom. Another useful visual representation that can be used is the use of photographs.

2.6 Photographs

Photographs have been one of the first visual representations to be used extensively in science textbooks as an effective means of describing scientific phenomena (Pozzer & Roth, 2003). The main function of photographs is to capture the reader's attention (Pozzer-Ardenghi & Roth, 2005). The use of photographs is seen as a means of promoting both the visual and the verbal mode as the learner try to construct meaning of a concept (Eshach, 2010). Even though one might argue that photographs are essentially static representations of reality, they are still worthwhile since they provide a visually rich representation of real events as they unfold. In relation to textbooks, the use of photographs is generally classified according to four categories, namely decorative, illustrative, explanatory and complementary (Gilbert, 2008; Pozzer-Ardenghi & Roth, 2005; Pozzer & Roth, 2003).

As illustrations, photographs are visual images that capture real situations therefore each type of photograph is used for a specific purpose (Pozzer & Roth, 2005). Explanatory photographs are used to describe scientific phenomena. Complementary refers to photographs that can compliment scientific theory by providing certain additional information that may otherwise not appear in the text theory. In view of these different types of photographs, there are an infinite number of ways that learners can use to interpret them. In a study conducted on the effectiveness and purpose of the use of photographs in biology textbooks, Pozzer and Roth found that photographic images are used to convey a specific message and should be used responsibly by textbook designers (2003). The structural element of including proper captions and text explanations attached to the textbook illustration is important in order to prevent any misunderstanding.

As illustrated in Eshach's study, photographs can also be seen as a source of misconception since reality is captured in a static form. One of the photographs used in the research, shows a billiard table with billiard balls and billiard sticks. It would be difficult for learners to interpret the effect of Newton's third law on the conservation of momentum since they have to interpret a dynamic situation from an imaginary perspective (Eshach, 2010). The missing

information with regards to the intermediate motion of the balls before and after collision may not be accurately captured resulting in learners struggling to grasp the concept. Despite misconceptions, Eshach supports the use as photographs from the perspective that it brings “colour and life in the study of physics” (Eshach, 2010, p.13).

2.7 Visual Analogies

The use of analogies as visual representations in science teaching has been widely researched (Matthews, 2007). In simple terms an analogy is defined as a form of comparison of similarities between two concepts (Treagust, Harrison & Venville, 1998). According to Treagust *et al*, analogies are seen as being useful in helping learners to understand abstract concepts better so that they can be more easily assimilated into the learner’s knowledge base. Analogies are representations of aspects of the learner’s real world that is used by the teacher to teach a particular concept that is usually abstract and does not relate to the learner’s real world.

Treagust *et al* demonstrated through their research that analogies can be used very effectively in teaching various aspects in chemistry. They infer that analogies can assist learners in visualisation of the abstract concepts especially relating to chemical bonding. In one of the examples, a teacher uses a set of coloured balloons as analogues in explaining the chemical bonding and shape of a methane molecule (Treagust, Harrison & Venville, 1998). The teacher tied four inflated coloured balloons together to resemble the shape of a methane molecule. The learners seem to have benefited immensely from this exercise since they were able use visualisation to relate the analogy to a methane molecule. Treagust *et al* (1998) however mentioned that the learner’s analogical reasoning would be very limited if the learners lack visual imagery.

2.8 Animations

Visual representations can take the forms of one, two and three dimensions. Gilbert (2008) acknowledges that all three representational forms are important for metavisualisation, and that learners must be able to translate concepts from the macroscopic to the microscopic level using dimensionality. The use of three dimensional representations has been highlighted as the best possible approach especially in viewing molecules and chemical bonding (Tasker &

Dalton, 2006). In their paper, Tasker and Dalton propose the use of 3D animations as a more effective way in the teaching and learning of chemistry.

The use of animations is becoming an extremely useful visual tool that teachers are currently using. Unlike photographs and diagrams that are classified as two dimensional and static, animations is dynamic representation that is able to capture real time motion when one is viewing scientific phenomena.

As a result of technological advancement, the use of computer generated animations and computer simulations have become useful forms of visual representations for teaching and learning of science. During these contemporary times, scientists and science teachers are using technology as a means of making their teaching more innovative and current. The use of computer generated programmes allows teachers to easily demonstrate models, diagrams, pictures, analogies and animations in three dimensional forms (Clark & Wiebe, 2000). Although much research has been done in demonstrating the value in the use of this type of technology in science education, I have identified two major challenges that are associated with the technology approach.

The first challenge relates to whether teachers have the necessary skills and teaching pedagogy to utilise computer technology in their classroom. In Shulman's pedagogical model, the need for teachers to be critical of their teaching methods and to constantly evaluate their effectiveness has been outlined. Teachers should always keep abreast with contemporary developments in education and should attend to all necessary post service teacher training programmes in order to utilise these new and innovative methods (Shulman, 1987). One of the problems is that teachers do not have the necessary training and expertise in this field of education, especially in developing countries like South Africa.

The second challenge relates to accessibility. Developed western countries may not experience this problem, however in most developing third world countries, including South Africa where financial constraints do not permit the majority of teachers and learners to have access to these new technologies. In South Africa, the limited resources relating to multimedia and infrastructure has been recognised as a disadvantage in terms of the learner's use of external representations in learning science (Mammino, 2008). As a result these learners are unable to develop mental models and visual images of chemical concepts and this

leads to poor conceptual understanding. These new technologies that are visually stimulating would certainly be useful in countries where learners perform poorly in science.

Despite these wide reviews, this study is aimed at focusing only on the use of pictorial diagrams/pictures and photographs as a means of visually representing scientific concepts to learners.

2.9 Chapter Summary

In this chapter, reviews of literature pertaining to learning difficulties in relation to conservation of linear momentum followed by the use of visualisation in science as a teaching strategy have been presented. Part of this chapter was a review of conceptual difficulties associated with conservation of linear momentum. One of the main problems that were identified was the learner's difficulty in interpreting the vector nature of momentum with respect to problem solving. The second part of the literature review focused on visualisation in terms of how learners can cognitively comprehend scientific concepts through the construction of mental models. As a means of constructing mental models learners are able to internalise concepts and think about them from a visual perspective. This process is termed metavisualisation. In order for this process to be beneficial to learning, the manner in which science is externally represented needed to be considered.

The merits and demerits of various external representations in the form of diagrams, photographs, analogies and animations were discussed with the specific aim of providing a general view of the place of visual representation in facilitating conceptual learning in Science.

In the next chapter the overall research methodology for the study is outlined.

CHAPTER THREE - RESEARCH METHODOLOGY

3.1 Introduction

This chapter outlines the overall design of the study and how it was conducted. It highlights the overall research strategy that was used. The structure and design of the various research instruments used to collect data are also discussed.

3.2 Research approach

The process of teaching and learning in the science classroom is dependent on essentially how much social interaction takes place between the teacher and his learners. As social beings, educators form an integral part of a social system since education is based within a social context. In research terms, if one is conducting research within such a social context it is deemed as social research (Denscombe, 2007; Opie, 2004). The research that was involved in this study was therefore classified as social research since the objective was to measure some of these social relationships and experiences between the teacher and his learners as they interact with a set of visual representations relating to the conservation of linear momentum.

Research approach or research strategy within a social context that involves researching “instances of a particular phenomenon” with a view of providing “in-depth accounts of events” involving real people, is a category of social research referred to as a case study (Denscombe, 2007, p. 35). In terms of educational research, a case study may focus on how a class of learners and their teacher would perceive a single instance or a particular teaching activity within a particular circumstance over a defined period of time (Hitchcock & Hughes, 1989; 1995). In literature regarding case study, the terms “single” and “particular” are emphasised and this characterises a case study to be very specific in terms of the topic, context and setting.

There are different approaches to case studies that one can embark upon and this research is based on an evaluative approach. In evaluative case studies, the researcher is required for example to judge the worthiness or merit of a particular educational programme or event that is taking place in the classroom at a given moment (Bassey, 1999). The objective of

evaluative case studies is to review the actions and consequences of certain educational decisions that were taken during the lesson. The evaluative nature of this study was highlighted through the need to enquire about the effectiveness or usefulness of a set of visual representation to a specific group of second language learners in overcoming some of their conceptual difficulties experienced in conservation of linear momentum.

According to Bassey (1999), a case study usually portrays a real-life context as opposed to a contrived context. The research design of the study satisfies this criterion since it examined a real classroom situation in a school in its natural setting. The social interactions that take place in the classroom with respect to the visual representation were to be recorded within a particular context that was real as opposed to, for example, experimental studies where conditions are manipulated or artificially created.

The outcome of case study research is to establish a generalisation or conclusion about the population which the case represents (Bassey, 1999; Denscombe, 2007). The generalisations made are usually specific in nature and are only relative to any one of the participants involved in the study. It is therefore very difficult to make general conclusions outside of the parameters of the study since the outcomes of the study may not be relevant to the broader community.

3.3 Methods of collecting data

Numerous research procedures can be employed when one is compiling evidence during a case study, including use of interviews and questionnaires (Bassey, 1999; Denscombe, 2007). The methods of collecting data for this study were in the form of a learner's questionnaire, learner's interviews, a teacher interview and observation of the learner's interactions with the visual representations during the classroom lesson.

3.3.1 Learner's questionnaire

Questionnaires are ideal for collecting data for case study purposes since the data gathered is based on the participant's views on specific events or existing conditions at a particular moment in time (Cohen & Manion, 1994). Since the learner participants of this study were

required to give their views on a specific lesson, the choice of using a questionnaire in order to capture the learner's views was an ideal option.

The decision to use a questionnaire was also influenced by the large number of participants that were encountered in the study. The questionnaire was utilised since it was viewed to be less time consuming, self administered, easy to answer and provided a range of open ended and closed ended questions (Fraenkel & Wallen, 1990). Based on these reasons, the questionnaire was therefore seen as the most appropriate instrument for the gathering data from the learners in this study.

Many issues need to be taken into consideration when designing a questionnaire. Issues relating to time constraints in relation to length of the questionnaire and the general layout of the questionnaire had been taken into consideration during the design process (Opie, 2004). Some of these were used during the designing of the learner's questionnaire in this study.

The issue of time constraints was a real problem in this study since the lesson period was 45 minutes. From the onset it important to determine how much of time was required for both the lesson and the questionnaire to be completed within the 45 minute time frame. The estimated time that was allocated to completing the questionnaire was 15 minutes. Establishing a time limit was important with respect to determining the length of the questionnaire. It was decided that the length of the questionnaire should be restricted to a maximum of 15 questions; hence the learners would be given approximately a minute of time to answer each question.

After deciding on the length of the questionnaire, the next stage involved the designing of the questions. The questions needed to be based on the broad research questions. To this end, the questionnaire was divided into two sections with each section relating to the two research questions of this study. The first section entitled "Language of Instruction" consisted of four short closed ended questions and one open ended question that requested information with regards to language and understanding (refer to Appendix E). The closed ended questions were used mainly to determine statistical information relating to language usage. The second part of the questionnaire entitled "Learner's response to the lesson" required learners to give their personal views and opinions, for this purpose the question construction had to be open ended. Open ended questions generally demand free responses

from participants (Neuman, 1994); hence it was important to ensure that the questions were specific.

During the designing of the questionnaire, important decisions had to be made with regards to the question content, question wording, response to questions and the place of the question in the sequence (Cohen & Manion, 1994). In terms of question content it was important to select questions that were only relevant to the two broad categories mentioned above. For the first category, “Language of instruction” the objective was to obtain information from the participants regarding their daily language use in their homes and at school. The questions were then designed according to these objectives. For example, one of the objectives of the questionnaire was to enquire about the language that the learners spoke at home. This objective was then translated into a closed ended question and phrased as, “What is your home language/s?”

In designing questions for the second category, “Learner’s response to the lesson”, the primary objective was to determine the effect of the visual representation on the learning process. The intention was to determine whether the participant’s understanding of the concept momentum had improved through the use of the visual representations. In order to measure the understanding, the learning difficulties associated with conservation of linear momentum had to first be identified through the questionnaire. Another objective was to determine the participant’s views on the learning of physical science in general. These type of questions were designed as open ended questions since they would require the learner participants to express personal views and opinions. The following is an example of an open ended question used to determine the impact of the visual representation on the learning process, “Did the use of the pictures in the lesson help you in any way? Explain your choice of answer.” (refer to Appendix E).

The wording and general phrasing of the questions had to ensure that they were not ambiguous or misleading in any way (Neuman, 1994). Generally the questions in this study were constructed in very simple language and were short, straight forward and specific. The sequencing of questions was such that they followed each other in a natural way which gave the learner the opportunity to build on his responses in a logical manner. For example, the question involving the usefulness of the pictures would elicit general responses about their feelings about the visual representation. The next question follows up on these feelings by

asking the learners what exactly did they “like and dislike about using the pictures”. The learners would now have to build on and expand on their previous ideas. This approach of structuring the questions was adopted throughout the entire questionnaire.

Upon completion of the questionnaire, a pilot study was conducted to determine whether the instructions were clear, the length of the questionnaire, structure, wording and sequencing of the questions were suitable (Opie, 2004). For this purpose, two learners from my science class who matched the grade level and background of the intended learner participants were used. The results from the piloted questionnaire, led to the adaptation and refinement of the questionnaire to its final state.

3.3.2 Learner’s interview

The second method that was used to collect data was a semi structured interview (refer to Appendix G). As opposed to a structured interview, this type of interview allows a little more flexibility since the researcher is given the opportunity to “probe and expand” some of the responses given by the respondents (Hitchcock & Hughes, 1995, p. 83). The intention of using a semi-structured interview for this study was to further engage learners on their views and attitude regarding the lesson. The semi-structured nature of the interview was to ensure that some of the learners were able to elaborate and expand on some of their responses, especially in relation to how the visual representation had helped them during their lesson. The justification of using such interviews was seen as a means of consolidating some of the data received through the questionnaires.

The learner’s interviews were to be conducted after the learners completed the lesson activity hence the objective of the interview was to determine how they had coped with the activity itself. The questions used during the interviews were based solely on the activity although there was some overlapping of certain questions from the learner’s questionnaire. This feature is not uncommon for a semi-structured interview since the questions are not completely predetermined and hence the researcher may decide to use some similar questions to that of other instruments used in the study (Hitchcock & Hughes, 1989; 1995).

In the construction of the learner’s interview, the questions were designed according to the objective of determining whether learner participants were coping with the classroom activity

and whether the visual representation had helped to remediate some of their learning difficulties in relation to conservation of linear momentum. In this regard, a set of four general questions were pre-constructed to be used only as a guide since their answers would be opinionated and may require further probing (refer to Appendix G). The idea to restrict the interview to a maximum of four questions would be adequate. It was envisaged that there would be three interviews conducted. Each was to last for about 2 to 3 minutes; therefore the questions needed to be short and direct.

Once the interview schedule was constructed, the only aspect that remained to be addressed was the manner in which the learner's responses were to be collected. The traditional option of the interviewer taking notes while the interviewee is responding can often be distracting to the interviewee since eye contact is temporarily lost and the interviewee is not given sufficient attention (Hitchcock & Hughes, 1989; 1995). It is also difficult to capture all the verbatim in written form. Based on these reasons, it was decided that the best and most accurate means of capturing the data was through audio recording the interviews.

3.3.3 Teacher's interview

The interview approach was also used on the teacher in this study. Interviews generally have the advantage of being able to provide data that has a greater depth than questionnaires since it provides participants with opportunities to verbally expand on their personal views and opinions (Cohen & Manion, 1994). The purpose of the interview was to elicit the teacher's feelings regarding the lesson and how the learners responded. To this end, the interview was the best means of gathering data from the teacher since it was to provide valuable insight into the teacher's personal opinions in a way that other instruments (such as a questionnaire) would not have been able to achieve. As in the case of the questionnaire and the learner's interview, it must be noted that the teacher's interview schedule was designed exclusively by the researcher according to the research objectives and questions.

The teacher's interview was different to the learner's interview since it followed a more structured format. Structured interviews require the researcher to prepare an interview schedule that contains a list of predetermined schedule of questions (Hitchcock & Hughes, 1989; 1995; Opie, 2004). The interview schedule for this study was designed with the

purpose of accurately capturing the teacher's sentiments about the usefulness of the visual representation.

The following stages were adhered to in relation to the preparation of the teacher's interview schedule. Firstly, careful consideration was given to how the research questions were translated into the interview questions. Secondly, the structure and the numbering of the questions must be determined. Thirdly, it had to be decided on how the responses would be captured (Opie, 2004).

As in the case of the learner's questionnaire, careful consideration was given to how the questions for the interview should be formulated and the order of questioning (Breakwell, 1995). With regards to question formulation, the approach that was adopted for the learner's questionnaire applied also to the teacher's interview. The questioning order was important and was followed rigidly since the interview schedule had to flow with rhythm (Breakwell, 1995). Once again in terms of this study, the interview schedule was piloted in order to ensure that it met with the necessary standards that have been highlight above. The interview schedule was piloted on a teacher colleague of similar background to the intended teacher participant. My supervisor was also involved in the evaluation of the teacher interview.

With regards to translating the research questions, unlike with the learner's questionnaire, the teacher's interview schedule was divided into four instead of two sections of the questionnaire (refer to appendix F). The first section of the interview schedule contained questions relating to the teacher's background. The objective of this section was to determine the teacher's home language, his teaching qualifications and his teaching experience in physical science. The first four questions were designed to achieve these objectives. The importance of this section was to gain some insight into the teacher's pedagogical competency.

The second part of the schedule focused on the second research question of this study, namely on learning difficulties in relation to language usage. The questions were designed to allow the teacher to rate his learner's language proficiency in the language of instruction. Other questions that were included in this section required the teacher to explain the use of English as the medium of instruction.

The third section of the interview schedule was designed to focus on the use of the visual representation and the impact it had on his learners. The type of questions that were constructed for this section was aimed at establishing what the teacher's personal views were on the visual representation, whether he makes use of pictures and other visual aids during his teaching. Finally in the last section the teacher has to explain what effect the visuals had on the learners and the learning process in general.

As in the reasons specified for the learner's interview, it was also decided to audio record the teacher's interview.

3.3.4 Observation

The final method used to collect data in this study was observation. Observation is recognised as being the most important method and is central to any good case study research that is carried out (Cohen & Manion, 1994). The objective of using observational procedures during a case study is often to carefully record the social interchanges that take place at a particular moment. In relation to this study, observation of the classroom lesson was essential since the researcher had to determine how the learners were interacting amongst each other and with the teacher during the lesson. The intention was also to determine whether the use of the visual representation was effective during the lesson and how the learners responded to it.

The type of observational approach that was selected for this study was a non-participatory approach which involves the researcher remaining aloof from the lesson itself during the observation of the lesson activity. Although the researcher does not participate in the classroom activity, his presence can affect the manner in which the participants would behave when they are being observed (Opie, 2004). Despite this limitation, observational studies are used extensively since there are more advantages to using it.

According to Denscombe (2007), the advantage of observational research is that it allows for the researcher to obtain direct evidence instead of only having to rely on what the participants are saying since the researcher is there to witness the events first hand. For this study, it was crucial for the researcher to personally witness the classroom interactions in

order to be able to report on how successful the interactions were in relation to the classroom activity during which the visual representation was used.

The objective of observation for the study served as a means of establishing a broad overall perspective of how the lesson would progress. Specifics such as the participant's "personal traits" and "professional skills", for example the teacher's classroom management, (Opie, 2004, p. 125) were not required. The only important aspect was to observe the teacher's pedagogical approach during the lesson and the learner's activity involving the visual representation. The type of verbal interaction between the teacher and his learners, as well as between the learners, would be the critical objective in determining whether the visual representation assisted in the teaching and learning of conservation of linear momentum. The observation schedule was designed with this specific objective in mind (refer to Appendix H).

The design of the observation schedule was adopted from an observation sheet used in Opie (2004, p. 127). The categories were slightly modified for the purpose of this study. For example, the aspect of code switching had to be included as a category of response in the observation schedule. There were separate categories of responses allocated towards the teacher and the learners. During the observation of the lesson, the recording of responses were systematically recorded according to the time of response, within the teacher category and the learner category respectively (refer to Appendix H).

Since the main objective of observing the lesson was to determine whether the visual representation was effective or not, the particular visual representations used in the study is now described in detail.

The choice of visual representation was important. When I initially tried to look for visual representations, the objective was to ensure that the representations were colourful and visually stimulating². It is a set of pictures depicting the various stages of the motion of two objects as they are about to collide. Each picture is accompanied by a table representing the mass, velocity and the calculated momentum values of the respective objects instantaneously. These pictures represent the different scenarios that are associated with two objects, namely,

² The visual representations used in this study were downloaded from the following internet sites: www.physicsclassroom.com.

a motor car and a truck colliding with each other. There are five scenarios and each one contains a set of pictures showing the sequence of events that takes place before the collision as well as after the collision (see Appendix R). Each sequence represents a particular time frame of the motion. By viewing the sequences all at once, one would be able to observe a continuous picture that is similar to watching the motion in real live time.

The first scenario represents the two objects traveling in the same direction with the car colliding with the truck and thereafter they separate. Scenarios 2 represent the two objects approaching each other and then collide, separate and then move in opposite directions. Scenario 3 represents the two objects traveling in the same direction but they do not separate after collision and continue traveling in the same direction after the collision. Scenario 4 shows the two objects approaching each other and, after the collision, the objects remain linked together as they continue moving. The final scenario is similar to scenario 4 except that one of the objects is traveling vertically through the air before the collision.

Four static photographs were also included, each one representing collisions taking place in everyday situations. The first photograph represents two cars colliding and the physical damage that has resulted. The second photograph represents a gun being fired. The third picture represents a cricketer's bat making contact with a cricket ball. The final photograph is similar to the picture of the colliding cars as it shows a collision and the impact created by the collision (refer to Appendix S).

The representations were meant to allow learners the opportunity to physically visualise the course of action during a typical collision that takes place between two objects. Hence the set of pictures and photographs that were selected had to have an impact on the learners and positively influence their learning. More specifically the visual representation was meant to assist the learners in overcoming learning problems relating to conservation of linear momentum (as discussed in section 2.2). During the lesson, I observed the classroom interactions between the teacher and the learners regarding their interpretations of the visual representations.

The process of carefully selecting and designing the instruments for data collection for the study was guided by the broad research objectives and research questions outlined earlier.

Table 3.1 illustrates the research methods chosen in relation to the research questions and objectives for this study:

Table 3.1: Research Methods and Objectives

Research questions	Data collection method used	Objective of data collection method
Does the use of visual representation in the form of pictures and photographs, help to promote better conceptual understanding in physical science?	Learner's questionnaire Learner's interview Observation Teacher's interview	To collect data in relation to: <i>1. Learner's conceptual difficulties with conservation of momentum.</i> <i>2. Impact of visual representation on the learning of conservation of momentum.</i>
How do these visualisation strategies help second language learners in bridging the gap in conceptual understanding due to language difficulties?	Observation Teacher's interview	To collect data in relation to: <i>1. Impact of language of instruction on learning</i> <i>2. Impact on visual representation on second language learning</i>

3.4 Chapter Summary

In this chapter the research that was to be conducted was a case study involving a selected group of learners and their teacher participating in a classroom lesson that focused on the conservation of linear momentum. Included are steps involved in the selection and design of appropriate research instruments that were used to collect the data.

In the next chapter, the sampling process and the actual data collection is discussed.

CHAPTER FOUR - SAMPLING AND DATA COLLECTION

4.1 Introduction

The objective of this chapter is to give a detailed account of how the actual study was conducted. It starts by introducing the process of identifying and selecting the research participants for the study. This is followed by an account of how the data was collected.

4.2 Sampling

When a researcher embarks upon a study, one of the initial decisions that have to be taken is in relation to sampling. Careful consideration is given to this aspect of the study since the selection of the relevant population has a bearing on the overall focus of one's study (Cohen & Manion, 1994). The first stage of sampling involved the identification of a suitable research site for conducting the study.

4.2.1 Research site

The word "former model C" and "township" school has become common reference terms that many teachers use when making comparisons between schools of different socioeconomic backgrounds. This form of categorisation is as a result of the past education system which distinguished the schooling system according to race groups. The model C schools that were created for the more privileged white communities were well resourced and financed whereas at the other end of the spectrum was the township school that was created for the less privileged black communities. Township schools were given minimal support in terms of finances and resources. As a result many of the township schools do not have proper teaching resources, infrastructural buildings and facilities in comparison to former model C schools (Howie, 2003; 2005; Ramnarain, 2010). Such disparities have existed historically, and are still a point of contention in present times, as they have not been adequately addressed (Ramnarain, 2010).

Township schools are often under financial constraints as a result of the difficulty that the schools experience with regards to the collecting of school fees. This type of problem is more common in township schools rather than former model C schools due to high levels of

unemployment within the communities in which such schools are located. The poor socio economic conditions of these communities have often led to the parents of the learners being unable to support the school financially (Ramnarain, 2010).

Besides the non payment of school fees, many learners in township schools do not have textbooks and stationery for school hence learners in such schools are seriously disadvantaged when compared to learners from other more advantaged communities represented by the former model C schools yet, educationally, they are expected to perform at the same level.

The school selected for the study was a typically South African township school located in the east of Johannesburg. The reason for selecting this particular school was due to certain circumstances. Firstly I was already familiar with the school after visiting it on a previous occasion where I attended a departmental workshop and became acquainted the headmaster. Secondly the school was situated very close to where I live and seemed a convenient option. My reason for selecting a township school rather than a former model C school was primarily that the sample group needed to be second language learners. Another reason for selecting a township school was because poor performances in mathematics and science and general learning difficulties are more common in such schools (Howie, 2003; 2005). In terms of answering my research questions, the participation of a township school would have far greater significance to my studies in comparison to a former model C school especially with regard to both the language of instruction and resources for teaching science.

In terms of physical science, the school caters for four classes of grade 10, three classes of grade 11 and three classes of grade 12. There are two senior science teachers that are responsible for teaching these classes. The class sizes range between 30 to 40 learners. I also found this to be high compared to former model C schools where the class sizes range between 20 to 30 learners.

Although the school has two science laboratories, they are not fully equipped. For example, there was no gas or running water and the store rooms contained little scientific apparatus and chemicals. There were also no overhead projectors available for use in the class as the teacher had mentioned to me that there was only a limited number for the entire school and one had to borrow if necessary. In terms of the study this seemed relevant with

respect to whether teachers had the adequate resources necessary for the use of visualisation strategies during their teaching.

4.2.2 Learner participants

It has been mentioned, in section 1.2 (page3) with reference to Howie's research regarding the results from the TIMMS test, that poor language proficiency can have a negative impact on learning. It was further explained that second language learners in particular would experience conceptual difficulties (Howie, 2003). The second research question of this study intends examining this aspect more closely, therefore for the purpose of this study the sample group selected had to be specific as they needed to be second language learners.

The sample of learners that I had initially intended to use was the grade 11 learners. The reason for selecting grade 11 learners was based on the notion that they have seen how science can be presented in different ways, and were expected to be in a better position to be able to comment on the effect of the visual representation when compared to learners in the junior grade levels. The limited exposure and experience that junior learners have in science would therefore not make them ideal candidates for this study. Senior science learners were therefore selected because the physics topic of interest (conservation of linear momentum) is only taught at this level.

I had not planned to use grade 12 learners as participants as they would be busy with preparation for their examination and would not be available at the time when my study would be conducted. This scenario however changed when it was closer to the time for me to collect data. Unforeseen circumstances in the form of a national teacher's strike (I will elaborate further on this matter in the data collection section 4.3.4) arose which led to me having to change my sample group from the grade 11 to the grade 12 learners. At the stage of conducting my data collection, the grade 11 learners had not completed their syllabus regarding the conservation of linear momentum and I was compelled to use the grade 12 learners who had. The choice of grade 12 learners was therefore the best alternative since I did not have to make any changes to the design of the study and the objective of the study remained intact.

The particular grade 12 class that was selected had 31 learners; all agreed to participate in the study and were used as participants. This particular grade 12 class was one out of the three classes that existed at the school. The selected learner participants, according to school records were of average abilities in physical science.

4.2.3 Teacher participant

It was imperative that the teacher participant in the study had the necessary competency and teaching experience. The choice of the teacher participant was made easy since there were only two qualified senior science teachers available of which only one of them taught at a grade 12 level hence the decision was straightforward. The initial intention of using both teachers was not possible in light of having to change the learner sample as a result of the strike action (refer to section 4.3.4).

The teacher participant in the study turned out to be experienced and competent. He had been teaching physical science at grade 11 and 12 level for the past nine years. He was qualified with a postgraduate certificate in education specialising in physical science. The teacher's credentials reflected that he was a suitable participant for the study.

The teacher was approached in order to obtain his permission to become a participant in the study. The task of convincing the teacher to participate was not difficult as he was very enthusiastic and displayed a willingness to help with the study. He indicated that he intended to revise the topic of conservation of linear momentum as preparation for the learner's preliminary examinations and this study would present him with an ideal opportunity to do so.

Although the teacher gave his verbal consent to participate in the study, written consent was also obtained (refer to section 4.3.2). The sampling was finalised and the next stage was to proceed with the data collection.

4.3 Data collection

Collecting data within a social context such as a school requires careful planning and consideration must be given to all stages that include, gaining access to the research site, securing informed consent of the participants and outlining the actual data collecting process. These stages will be explained in following paragraphs:

4.3.1 Gaining access

As with any ethical social research, the initial stage starts with the researcher having to seek official permission from the institution where he intends carrying out his research (Hitchcock & Hughes, 1989). The principle behind gaining access lies in the fact that research can be seen as a potential intrusion since it can sometimes be disruptive to the normal functioning of the institution (Cohen & Manion, 1994).

In view of the above, my first task was to make a formal application to the University of Witwatersrand ethics committee for ethical clearance (refer to Appendix A for a copy of the letter from the university granting ethics clearance for the study). Secondly, I had to make a formal application to the Gauteng Department of Education requesting their permission to conduct research in one of their schools. This process involved the completion of a standardised application form, which required me to give insight into my research project. I was required to submit the name of the school at which the research was to be conducted at; my proposed research methods in terms of collecting the data and also information regarding my sample selection (refer to Appendix B for a copy of letter of approval received from the Gauteng Department of Education).

In order to gain access to the research site, I wrote a formal letter to the school principal stating my intentions (copy in Appendix C). In my letter, I firstly mentioned briefly what my research objectives were and then outlined the process that I envisioned for data collection. I mentioned that I would be working with two physical science teachers and working with two grade 11 classes as participants. The teachers would be required to implement a particular teaching strategy in one of their lessons and I, as the researcher, would be present to collect data. I mentioned the type of data collection methods that I would be using and that the data

collection process would cause minimal disruption to the school timetable. I had also stated that the results of the research may have significance in terms of improving the teaching and learning of physical science in South African schools.

The letter was a mere formality as I was then requested by the principal himself to meet with him in order to conclude the final arrangements regarding the data collection. The initial meeting was most critical since it is at this point where the researcher has to make an impression on the principal and develop a “research relationship” (Opie, 2004, p. 29). A research relationship is essentially a mutual relationship between the researcher and his participants whereby there should be benefits out of the research for both sides. This relationship would require both sides to be open and upfront with each other. As a researcher, it was therefore very important for me to be as detailed as possible with the principal regarding my plans. I had to also ensure that I made my intentions clear to him from the onset.

The principal was very accommodating towards my needs. The principal gave me formal permission to use his school in my research through a letter (see Appendix D). He referred me to the school’s head of the science department with whom I developed a very close working relationship. Again, in terms of research principles, this type of working relationship is crucial for the success of the research (Cohen & Manion, 1994). The head of department was instrumental in helping me with my sample selection. He arranged for me to meet with two physical science teachers, one of whom would go on to become my research participant (details of this has been given in the Sampling section 4.2.3).

4.3.2 Informed consent

The next stage was to obtain informed consent from the research participants since social research demands that the consent and cooperation of the participants needs to be obtained prior to data collection (Cohen & Manion, 1994). The securing of written informed consent is important for the researcher since it would be illegal and unethical for him to collect data without gaining the permission of the respondents participating in the research.

The process of gaining informed consent was obtained in steps: Firstly the participants were informed about the proposed research, what it entails and what role the participants play

in the research (refer to Appendix I and J for Participant information sheet). The teacher participants were briefed on the research objectives and their intended roles in the research. This had taken place during my meeting with the teachers. They were informed that my study focuses on how the teaching of physical science can be influenced by the use of visual representation and its impact on the teaching and learning process. In terms of what they were expected to do, I requested that they teach a lesson on the conservation of momentum using visual representation in the form of a series of pictures and photographs. They were informed that I, as the researcher, would be physically present at the lesson in order to capture data for the research purpose.

Secondly, the researcher needs to brief the participants about the research procedure with regards to how the data would be physically captured. For this study, the teacher participants were informed that the data would be collected through the use of three research procedures, namely, observation of their lesson, requesting that learners complete a questionnaire and finally conducting interviews with some of the learners as well as an interview with the teacher after the lesson.

In terms of observation, I had indicated to them that I would be sitting in on their lesson as a silent observer recording the details of the lesson. The recording of the lesson would involve physically writing notes in an observation sheet. The second means of recording would be done through audio recording of the teacher's and learner's verbatim through audio recording. After the teacher presented the lesson, I would then proceed with the learner interviews.

These would be conducted randomly with some of the learners after they had completed the class activity. They were informed that three learners would be chosen randomly on the day of the actual lesson and that the interviews would take place after the activity. In order for me to conduct these interviews, as well as to audio record the learner responses, informed consent for the entire learner sample was needed in order for me to randomly select and interview them. After the random interviews, the learners would then be asked to complete the questionnaire at the end of the lesson after which I would interview the teacher using a predetermined interview schedule (refer to Appendix F).

After the research participants had agreed to what their roles were during the research, written informed consent was then obtained prior to data collection. The research participants gave their formal consent by completing a consent form (see signed copy sample in Appendix O). There were 31 learner consent forms completed. The teacher consent form detailed that the teacher had given the researcher permission to observe the classroom lesson, make an audio recording of the lesson presentation as well as consent to being interviewed at the end of the lesson (refer to Appendix L and M for copies of consent forms). The learner consent form expressed that they had given the researcher permission to observe them during the lesson, to conduct random interviews as well as to use the information that they would give through answering the questionnaire (refer to Appendix K, L, M and N).

Once I had gained written informed consent from all participants, the next stage was to decide on a possible date on which the data could be collected. All parties agreed that it would be done on the 13th of August 2010. This date later had to be revised to the 10th of September 2010 as a result of the teachers strike (refer to section 4.3.4).

4.3.3 The class activity

After securing the informed consent and finalising the dates, I was ready to proceed with the planning and executing of the actual study. As mentioned earlier (in section 3.3.4), the study required the teacher to use a set of visual representations as part of their teaching strategy. The visual representation consists of a set of pictures and photographs based on the conservation of linear momentum.

As mentioned earlier (section 3.3.4), I informed the teachers that they were to use these pictures during their teaching. The teacher should first teach the lesson and then hand out a set of worksheets containing the visual representations. The teacher had to divide the learners into 5 groups of 7 learners. While working in their groups, the learners had to interpret the sequence of pictures for each scenario by determining whether linear momentum is conserved for each set. They needed to use the numerical values from the table provided to calculate the combined momentum of the two objects in each instant in order to make the prediction that the linear momentum is conserved. Following this, they were required to complete the second task involving the interpretation of the photographs. A general discussion would take place between the teacher and the learners once the activity was completed.

The learner participants involved in the research would have already been taught the conservation of linear momentum previously and the objective would be re-teach the lesson by utilising the visual representation as a form of intervention. During this time I would be present to collect the data which would ultimately provide evidence as to whether there would have been any change in the conceptual understanding of the learners after the intervention.

4.3.4 Challenges prior to data collection

As thoroughly prepared as one may be, the data collecting process could be jeopardized by unanticipated problems that could arise (Opie, 2004). One of my greatest challenges was in the form of the national public servant's strike which took place during the time I intended collecting data. The major teacher unions also joined the nationwide strike during the month of August in protest for a better salary. The month long strike resulted in minimal or no teaching and learning taking place as a result of many schools being forced to close. The school that I had selected to conduct my research had suffered the similar fate hence the strike played a significant role in delaying my data collection. I made contact with the school during the strike and was advised that I should collect the data as soon as the strike had subsided.

The other challenge that I faced, as a result of the strike, was that the intended two teachers and the two Grade 11 classes that would have been the initial participants would have not been prepared since they had lost a month of teaching and learning time. After much consultation with my supervisor and one of the participant teachers, I decided that we would continue with data collection immediately after the strike but we needed to change the sample group with regards to the learner participants. According to my research plan, we needed to implement the teaching strategy on a group of learners who had already encountered the syllabus relating to conservation of momentum.

Despite the ethical concerns that the grade 12 learners were about to embark on writing their preliminary examination, the teacher felt that they would be best suited as substitutes for the research due to them having already completed their studies on conservation of momentum (refer to section 4.2.3). Since the conservation of linear momentum is often included in the grade 12 examination, we felt that the learners would actually be advantaged;

this was an opportunity to revise this section of work. The second teacher was however unable to participate in the research since she was not teaching at grade 12 level (refer to section 4.2.3).

Once the informed consent was gained for grade 12 learner participants and the teacher participant, the new date was finalised (refer to section 4.3.2). The next step was to conduct the actual data collection.

4.3.5 Conducting the actual data collection

On the day that I was scheduled to start collection of data, (10th September 2011), I decided to meet with the teacher for a final briefing session an hour before the scheduled lesson. In the final briefing session, the class activity as outlined in section 4.3.3 was discussed with the teacher. When the lesson started, I was seated at the back of the classroom in order to systematically observe the course of events unfolding during the lesson. Systematic observation entails that the researcher is not an active participant and therefore needs to be “invisible” in order not to interfere with the natural setting of the research site (Denscombe, 2007, p. 213). I therefore chose to sit at the back of the classroom in order to become less conspicuous to both the learners and the teacher. As the lesson proceeded I started by observing the type of interactions that was taking place and started to record in steps how the lesson unfolded and progressed during the 45 minute period. The lesson was also audio recorded and the teacher wore recording device attached to his shirt pocket.

During my observation I only recorded the first 20 minutes of the lesson in the observation sheet (see Appendix P) since the teacher had completed his presentation. After the teacher completed his presentation, he proceeded to hand out the visual representations. The learners then proceeded by working through the activity. After 15 minutes had passed I proceeded by conducting the learner interviews.

There were 3 learners that I selected randomly. The teacher asked these learners to move to the back of the classroom where I was positioned. This was done in an effort to avoid any unnecessary disruption to the rest of the class as they completed the activity. I interviewed each learner individually and audio-recorded the learner’s responses. I asked questions relating to how the learners were coping; what were some of the learning difficulties that they

had experienced prior to this lesson; and whether the visual representations had any impact on their understanding of conservation of momentum. These were predetermined as explained in the research design section (refer to 3.3.2). The questions that were asked were similar to the learner's semi structured interview schedule (refer to Appendix G).

The responses that I had received from the learners varied from good responses to incomplete responses. I considered certain responses to be incomplete since they did not relate directly to the question. For example in one instance when I asked a learner how the pictures had helped her in her understanding of momentum, she gave an incomplete response by saying that the visual representation had helped her to understand how objects "physically collide" and did not elaborate further. Based on such responses, I had to probe by using follow-up questions when necessary. As a follow up I would normally ask the learner to "elaborate" or to "explain further".

I initially planned to conduct three interviews, however, after the first three interviews I felt that the learners were not giving me sufficient data relating to my research questions. Their verbal responses were short and incomplete. At this stage I decided to continue by randomly interviewing another four learners. The objective was to ensure that I was thorough and had enough data that was relevant to answering my research question. The second set of learners was forthcoming and provided more detailed responses which I felt met my objectives. At this point I therefore felt that there was no need to conduct anymore learner interviews.

Finally, as the lesson time had drawn to a conclusion, the teacher decided that there was not enough time for the learners to verbally report back to the class on the activity. He collected the handout containing the visual representation from the learners as per my request and then handed out the questionnaires to the learners. The learners took approximately 15 minutes to complete the questionnaire. The collection of the questionnaires had signaled the end of the lesson. The only aspect that was left to carry out was the teacher interview. We arranged that the interview was to be conducted the following day as the teacher had run out of time.

The teacher interview was crucial since it was to provide a summative account of the lesson and serve to link up with the data that I had already received from the learner participants. The teacher interview was much more detailed and rigorous in comparison with the learner interviews. The type of questions that I asked the teacher through my interview schedule

(refer to Appendix F) focused around his teaching background; how the classroom language of instruction impacted on the learners understanding of physical science and his views on the impact of the visual representations on his learners.

The teacher's responses were very honest as he spoke openly about the effects of the classroom language on learning. He also gave several useful responses relating to views on the visual representation which were directly related to the research questions. All of the teacher's responses were audio recorded and the interview process lasted for approximately 20 minutes. At this stage the data collection was completed.

As a novice researcher, I found the data collection process to be very challenging and yet at the same time very exciting. For me the challenge of not knowing or predicting the outcome of what is going to happen during the actual data collection was a very daunting thought. Since I had not been involved in the actual lesson planning, I did not know what to expect in terms of how the lesson would pan out. The unpredictability of how the learners and the teacher would respond to the lesson was a concern for me. My other concern was the audio recording. The audio recording microphone was placed in the teacher's shirt pocket during the entire duration of the lesson. Although I had tested the equipment prior to the lesson, my fear was that it might not record clearly due to the classroom acoustics and other forms of interferences. Unlike in the movies where one can have numerous rehearsals and "retakes", my fear was that I had only one chance at recording the lesson properly and did not have the luxury of a second take. These feelings of paranoia prior to data collection would be normal for a novice researcher (Opie, 2004).

Despite my concerns and anxiety, I also felt a sense of excitement during the data collection process. I was excited about the prospect of going into the classroom and being able to finally collect the data. As I started to record observations as the lesson unfolded, I became less tense and started to finally enjoy the whole experience.

From my experience on the field, one of the things that I have learnt is that no matter how much planning and preparation that you have put into the data collection process never take things for granted since unexpected circumstances (as in my case with the national teacher's strike) may arise. Such circumstances can upset your plan of action for data collection. My experience has taught me that one needs to be flexible and to expect the unexpected in the

world of research. Despite the unexpected, at the end of the data collection process I was relieved that everything had eventually went ahead smoothly and I had successfully collected the data.

4.4 Chapter Summary

This chapter is a summary of how the actual study was conducted. The first part of the chapter explains the sampling process. The first stage involved the acquisition of ethics approval from the University to conduct the study. The next stage involved the selection of the research site. A brief motivation was given with regards to the selection and justification of the choice of the research site used in the study followed by a description of the procedures used to gain access to the research site. An explanation is provided as to how the research participants were selected and how their informed consent was obtained.

The second part of the chapter discusses the actual data collection phase of the research. It provides a detailed account of how the data for the learner's questionnaires, learner's interviews, the teacher's interview and the data from the observation of the lesson was administered and collected.

In the next chapter, the analysis and discussions of the data are presented.

CHAPTER FIVE - DATA ANALYSIS

5.1 Introduction

This chapter gives the details on how the data were analysed and interpreted. Especially discussed at the beginning is the type of analysis strategy that was adopted including how this analysis strategy helped transform the data into forms that could be used to answer the research questions. Attempts have been made to “stays close to the data as originally recorded” in order to ensure that the data must “speak for itself” (Wolcott, 1994, p. 10).

The data was analysed and interpreted in terms of the research questions of the study:

1. Does the use of visual representation in the form of pictures and photographs, help to promote better conceptual understanding in physical science?
2. How do these visualisation strategies help second language learners in bridging the gap in conceptual understanding due to language difficulties?

5.2 Analysis strategy

For the study, both the quantitative and qualitative approach was used. A qualitative strategy was adopted for the analysis of the learner’s interview, teacher’s interview and the observation. This involved dividing the data into typologies/categories for analysis (Hatch, 2002). Although categories were also used to analyse the learner’s questionnaire, a quantitative analysis strategy was used in this regard. The explanation and design of the typologies/categories for the learner’s questionnaire, learner’s interview, the teacher’s interview and the observation for the study follows in section 5.3.

Once the analysis categories were established, the next stage was to read through the data and mark off common ideas or evidence within the data that relates to each category. Each response from the participants was interpreted and placed within a particular category. In terms of my analysis, I recorded these ideas on a spread sheet within a particular column. Each column contained the category heading. Once the responses had been classified within the respective categories, the entries were re-read with the objective of looking for patterns and regularities to report on (Hatch, 2002).

The use of this analysis strategy was useful in analysing the questionnaire and interviews. The analysis and discussion for each group of data follows.

5.3 Analysis of learner questionnaires

With regards to the questionnaire analysis, seven categories were created as a guide to analysing the research data. These categories were established from the type of questions that were being asked through the questionnaire. The data was then looked at and a coding system was developed by using numbers to represent a particular type of learner's response. Table 5.3.1 represents categories that were established for analysing the questionnaire. Table 5.3.2 represents an expected coding of responses for categories 1, 2 & 3 in Table 5.3.1 which relate to language usage.

Table 5.3.1: Categories for questionnaire analysis

Category 1	learner's home language
Category 2	language used during instruction
Category 3	preferred language
Category 4	learner's attitude to physical science
Category 5	problems associated with the learning of conservation of momentum
Category 6	opinion of the learners towards the visual representation
Category 7	impact of visual representation on learning

Table 5.3.2: Codes for Learner responses for categories 1, 2&3

English	1
IsiZulu	2
Setswana	3
Xitsonga	4
Sepedi	5
Northern Sotho	6
All	7

The fourth category, namely the attitude of the learners towards physical science as a learning subject was derived through question 6 and 7 of the questionnaire. These two

questions ask the respondent whether they enjoy learning physical science and how the learning of physical science compares to their other school subjects (refer to Appendix E). Numerical codes to record the learner's responses were created in the form of the following descriptors: positive attitude, average and negative attitude as shown in Table 5.3.3.

Table 5.3.3: Codes for learner responses for category 4

Positive attitude	1
Average attitude	2
Negative attitude	3

The coding for the fifth category relating to problems associated with the learning of conservation of linear momentum was derived from question 8 and 9 (refer to Appendix E). These questions ask for the respondents to identify some of their leaning difficulties in physical science and specifically in relation to the conservation of linear momentum. The coding of responses for these questions is presented in Table 5.3.4.

Table 5.3.4: Codes for learner responses for category 5

Do not understand symbol representation associated with conservation equation	1
Understands symbols but cannot derive the equation	2
Problem solving relating to arithmetical calculations using the equations	3
Do not understand difference between elastic and inelastic collision	4
No problems experienced	5

The category of “opinion of the learners towards the visual representation” was derived from question 10 and 11 which enquires whether the respondents found the visual representation useful and what did they like or dislike about it (refer to Appendix E). Codes for the responses are represented in Table 5.3.5.

Table 5.3.5: Codes for learner responses for category 6

Liked using the visual representation, found it useful	1
Disliked the visual representation, found it unhelpful and confusing	2

Category 7 relates to the learner's responses to question 12 and 13 of the questionnaire. This final category describes the impact that the visual representation had on the learning process is presented in Table 5.3.6.

Table 5.3.6: Codes for learner responses for category 7

was extremely helpful in promoting better understanding of concepts – positive impact	1
pictures had no impact on learning – negative impact	2

Once the coding system was completed I then proceeded to analyse the questionnaires. Since the questionnaires were anonymous, I firstly numbered each questionnaire in numerical order to ensure that the data was accurately recorded and well organized for each specific questionnaire. The numbering would also make it easy for me in terms of referencing if I had to quote a learner's response from a particular questionnaire.

During the analysis I read through each of the 31 questionnaires and attached a code number to each of the learner's responses. The code number for each response was entered on an excel spreadsheet under the seven categories mentioned above. Table 5.3.7 is a record of the data analysis of the questionnaires. The key below the table represents the various categories of analysis that have been used. It can be seen that these correspond to the codes already detailed in Table 5.3.2 – 5.3.6.

Although I did not get anyone else to code the data and check the reliability of the coding, I felt that the pilot study and my supervisor's input had been sufficient.

Table 5.3.7: Data analysis of questionnaires

	Category 1	Category 2	Category 3	Category 4	Category 5	Category 6	Category 7
QUESTIONNAIRE No.	Home language	Class language	Preferred language	Attitude to Physical Science	Learning Problems	Opinion toward the Visual Represent	Impact on Learning
1	2	1	1	1	3	1	1
2	2	1,2,7	1,2	1	1,2,3,4	1	1
3	3	1,3	1	2	1,2,3,4	1	1
4	3	1,7	1	1	3	1	1
5	2	2	2	2	3	1	1
6	4	1,7	1	1	2,3	1	1
7	3	1,3	1	1	2,3	1	1
8	2	1,7	1,2	3	2,3	1	1
9	5	1	1	2	2,3	1	1
10	5	1,5	1	1	4	1	1
11	6	1,5	1	1	2,3	1	1
12	4	1,7	1	2	5	1	1
13	3	1	1	1	3	1	1
14	2	1,7	1	2	5	1	1
15	3	1	1	2	4	1	1
16	4	1,7	1	1	1,2,3,4	1	1
17	2	1,5	1	2	4	1	1
18	2	3	1,2	3	4	1	1
19	2	1	1	1	3	1	1
20	2	1	1	1	2,3	1	1
21	4	1,5	1	1	3	1	1
22	5	1	1	1	0	1	1
23	4	1	1	1	2,3	1	1
24	4	1,7	1	3	3	1	1
25	2	1,5	1	1	0	1	1
26	6	1,2,6	1	2	2,3	1	1
27	5	1,5	1	1	1,2,3,4	1	1
28	6	1	1	1	4	1	1
29	5	1,5	1	1	3,4	1	1
30	3	1	1	1	4	1	1
31	4	1,2,5	1	2	2,3	1	1

Key

Categories 1 to 3	
English	1
IsiZulu	2
Setswana	3
Xitsonga	4
Sepedi	5
Northern Sotho	6
all	7

Category 4	
Positive	1
average	2
negative	3

Category 5	
Do not understand symbol representation	1
Understand symbols but cannot derive equations	2
Problem solving in terms of arithmetic calculations	3
Difference between elastic and inelastic	4
No problems experienced	5

Category 6	
Like - found it useful	1
Dislike – unhelpful	2

Category 7	
Positive - promotes better understanding	1
Negative impact	2

The final step to completing the analysis involved the tallying of the code numbers and finally sorting in order to look for any possible trends and thereafter report on the results (See Table 5.3.8 & Table 5.3.9 respectively).

Table 5.3.8: Questionnaire analysis

Category 1	Category 2	Category 3	Category 4	Category 5	Category 6	Category 7
Home language	Class language	Preferred language	Attitude to Physical Science	Learning Problems	Opinion toward the Visual Represent.	Impact on Learning
2	1	1	1	0	1	1
2	1	1	1	0	1	1
2	1	1	1	1,2,3,4	1	1
2	1	1	1	1,2,3,4	1	1
2	1	1	1	1,2,3,4	1	1
2	1	1	1	1,2,3,4	1	1
2	1	1	1	2,3	1	1
2	1	1	1	2,3	1	1
2	1	1	1	2,3	1	1
2	1	1	1	2,3	1	1
3	2	1	1	2,3	1	1
3	3	1	1	2,3	1	1
3	1,3	1	1	2,3	1	1
3	1,3	1	1	2,3	1	1
3	1,5	1	1	2,3	1	1
3	1,5	1	1	3	1	1
4	1,5	1	1	3	1	1
4	1,5	1	1	3	1	1
4	1,5	1	1	3	1	1
4	1,5	1	2	3	1	1
4	1,5	1	2	3	1	1
4	1,7	1	2	3	1	1
4	1,7	1	2	3,4	1	1
5	1,7	1	2	4	1	1
5	1,7	1	2	4	1	1
5	1,7	1	2	4	1	1
5	1,7	1	2	4	1	1
5	1,7	2	2	4	1	1
6	1,2,5	1,2	3	4	1	1
6	1,2,6	1,2	3	5	1	1
6	1,2,7	1,2	3	5	1	1

Table 5.3.9: Questionnaire analysis (Sorting)

Category 1	Category 2	Category 3	Category 4	Category 5	Category 6	Category 7
Home language	Class language	Preferred language	Attitude to Physical Science	Learning Problems	Opinion toward the Visual Represent..	Impact on Learning
2 = 10	1 = 10	1 = 27	1 = 19	*0 = 2	1 = 31	1 = 31
3 = 6	2 = 1	2 = 1	2 = 9	1,2,3,4=4		
4 = 7	3 = 1	1,2 = 3	3 = 3	2,3 = 9		
5 = 5	1,3 = 2			3 = 7		
6 = 3	1,5 = 7			3,4 = 1		
	1,7 = 7			4 = 6		
	1,2,5 = 1			5 = 2		
	1,2,6 = 1					
	1,2,7 = 1					

* There were two learners that did not answer the question on learning problems.

The discussions of the above results are explained under each category heading as follows:

5.3.1 Language (category 1, 2 &3)

As evident in Table 5.3.8 and 5.3.9, there were six different home language categories. None of the learners had English as their home language. The majority of the learners in the classroom used IsiZulu (32%), followed by Xitsonga (23%), Setswana (19%), Sepedi (16%) and Northern Sotho (10%) as their home languages. Some learners were conversant in more than one home language.

Instead of the home languages, the results indicate that English is the dominant classroom language (Refer to category 2 of Table 5.3.9). While 10 learners (32%) indicated on their questionnaire that they used English exclusively, 19 learners (62%) indicated that they used English together with a mixture of other indigenous languages during their class interactions.

With regard to the learner's preferred language for classroom instruction, 27 learners (87%) indicated that they still preferred learning physical science solely through English as a medium of instruction (refer to category 3 of Table 5.3.9). While this finding was not anticipated, this pattern has also been observed and well documented in one other South

African study namely Setati's research into how teachers and learners position themselves in relation to language usage though this was in a multilingual mathematics classroom (2008).

5.3.2 Attitude to Physical Science (category 4)

Learners were classified as having a positive attitude if they indicated that they enjoyed learning science at school. A negative attitude therefore implied that the learners expressed complete dissatisfaction towards the learning of science in relation to their other school subjects. If the learner indicated that he sometimes enjoyed learning science or exhibited a preference to only the physics or chemistry content, this was classified as "average attitude".

With regards to the learner's attitude to physical science, the results indicate that the majority of the learners (61%) had a positive attitude (refer to category 4 of Table 5.3.9) to physical science. This is encouraging especially in light of the fact that the majority of the learner's (through their answer to question 7 of the questionnaire) found physical science to be one of the more challenging school subjects that they encountered.

Despite having a positive attitude this study showed that learners still experienced learning difficulties in their understanding of the conservation of momentum as discussed in the next section.

5.3.3 Learning problems associated with conservation of linear momentum (Category 5)

With regards to learning difficulties, the learners were asked in the questionnaire to state some of their learning problems that they had experienced in their learning of the conservation of momentum prior to the study. These results obtained from their responses indicated that the majority of the learners experienced difficulties in performing the arithmetic calculations as well as translating word problems into formula writing (Bryce & MacMillan, 2009; Grimellini-Tomasini et al, 1993). A total of 21 learners out of the 29 sample indicated this on their questionnaires (See Table 5.3.3.1 below).

Table 5.3.3.1: Learning difficulties associated with conservation of momentum

Type of learner responses	No of learners
- do not understand symbol representation associated with conservation equation - understands symbols but problems with deriving the equation - problem solving relating to arithmetical calculations using the equations - do not understand difference between elastic and inelastic collision	4
- understands symbols but problems with deriving the equation - problem solving relating to arithmetical calculations using the equations	9
problem solving relating to arithmetical calculations using the equations	7
- problem solving relating to arithmetical calculations using the equations - do not understand difference between elastic and inelastic collision	1
do not understand difference between elastic and inelastic collision	6
no problems experienced	2

* 2 of the learners out of the 31 sample did not to answer the question on learning difficulties

All of the 21 learners indicated through their answers to question 9 of the questionnaire (refer to Appendix E) that they could not translate word problems into the conservation equation since they could not correctly interpret the direction of the motion.

The other notable learning difficulty was the inability of some of the learners to be able to distinguish between an elastic collision and an inelastic collision. A total of 11 learners expressed their lack of understanding in this regard.

An interesting statistic is the fact that only 2 learners indicated that they had experienced no learning problems relating to conservation of momentum (refer to Table 5.3.3.1). The rest of the other 27 learners (except for 2 learners who opted not to answer this question) mentioned some type of learning problem.

5.3.4 Learner's opinion of the visual representation (Category 6)

The introduction of the visual representation during the lesson was a critical intervention that the teacher would use in order to try and address the learning problems that were experienced by the learners prior to the study (discussed in section 5.3.3). The visuals were handed to each learner and the teacher proceeded to explain the momentum calculation in

terms of the *before*, *intermediate* and *after* stages which were captured in the sequence of pictures.

All 31 learners enjoyed interacting with the visual representation and found it useful (refer to category 6 of Table 5.3.9).

5.3.5 Impact on learning (Category 7)

The data from Table 5.3.8 and 5.3.9 in relation to impact on learning (category 7) indicated that all 31 learner's responses matched the code 1 response which suggests that the visual representations contributed positively to promoting better learner's understanding of momentum concepts. All 31 learners felt that by physically seeing what was going on, they were in a better position to interpret the problem relating to conservation of momentum. This evidence was provided in the learner's answers to question 13 of the learner's questionnaire (refer to Appendix E). One of the learners also commented in the open section of the questionnaire that it is easier to understand the pictures rather than interpreting from "written statements".

Problem solving in conservation of momentum and most physical science work is represented as daily scenarios in the form of word problems. As highlighted in section 5.3.3 (learning difficulties), the majority of the learners (21 learners) indicated that they had experienced difficulty in problem solving with regard to direction. These 21 learners also indicated that the pictures helped in clarifying the aspect of direction that is associated with word problem solving. This finding was also captured in some of the learner's verbatim during the learner's interview (refer to section 5.4).

5.4 Analysis of learner interviews

In addition to the questionnaires there were also seven interview transcripts that I obtained from the learners that required to be analysed. The interview recordings were firstly captured into text form after which they were analysed using the following categories: "learner's ability to cope with the work", "learner's difficulties", "learner's view on the visual representation". The learner's verbal transcripts were analysed by reading through the

transcripts repeatedly and segmenting their responses within these three categories. Table 5.4.1 represents some of the learner's responses in relation to the above categories:

Table 5.4.1: Learner's interview analysis transcripts

Learner	Coping with the activity	Difficulties experienced	Usefulness of visual representation
*Zandile	I am coping very well	I am understanding the conservation of momentum...I do understand momentum	Yes they do help me to understand the work better. They show me ...physical collide (inaudible)... physical movement so when they collide there you can see the picture movement.
*Rondi	So far I am coping, I done the sums several times and I think I understand it very much	Not yet	They help me understand that..how do you mean when you say that collision is elastic and inelastic... It also makes me to understand what is meant by momentum before and momentum after ...Ya they are very useful because they show each and every step ...Ya I think the pictures are making it easier cause everything is clear
*Lebo	I am coping well	No,...not any more, I used to find it difficult but today is easier...yes I would find them difficult (word problems without pictures)....Because the questions that they might ask, I normally do not understand the direction in which the object is moving	The pictures... the diagrams, the way they presented them...Un... the way they show the direction that they both move and the masses are given, it makes it easy for me to understand.
*Mandla	Yes, they are good		Because it is something that you see in everyday life and sometimes we know that they exert different forces at the same time, so they wouldnt stick together...I think they are because now you can see a better view of what is happening rather than being told about what is happening without being given any pictures
*Delia	No response		Yes it is helping me, by looking at the picture I can see the direction of the two objects, like when they collide and like when they move apart and so on.
*Sipho	They are very helpful		When you are calculating it is easier to place the positive and the negative signs because it becomes difficult in words when they say one object goes east and the other goes west, so if you see them dramatically then it makes it easier to put signs and calculate...Also to notice which object they are talking about because the one minute they might say object A of this mass and then object B... they kind of mix the velocity of the two objects so (learners is confused by velocities) ... so therefore we wouldnt be sure which velocity is for which object.
*Mojaki	No response		ya, it like er can be used to identify when the collision takes place and in which direction the object is coming from Inaudible

** For ethical reasons, the names of the learners have been changed*

The results show that the majority (5 of the 7 sample) of the learners had coped well with the activity. The learners had verbally indicated this when they were asked about the activity, their reply was, “I am coping well” (refer to column one of Table 5.4.1).

According to the analysis of the interview transcript, 5 of the 7 learners indicated that they experienced difficulties in interpreting the correct direction of the colliding objects during the motion. All the learners found that the learning process was made easier with the use of the visual representation since this had helped them in terms of predicting the direction of motion (refer to column two of Table 5.4.1). The following transcript of one of the learner’s interviews highlighted this point:

- Researcher* : Ok, what aspects of momentum do you find difficult understanding?
- Lebo* : No,...not any more, I used to find it difficult but today is easier
- Researcher* : What is easier about today, what is making you understand better?
- Lebo* : The pictures... the diagrams, the way they presented them.
- Researcher* : In what way are the pictures useful to you?
- Lebo* : Un... the way they show the direction that they both move and the masses are given; it makes it easy for me to understand.
- Researcher* : So normally in a word problem, do you find it much more difficult to understand if the pictures are not there?
- Lebo* : Yes I would find them difficult
- Researcher* : And why is that?
- Lebo* : Because the questions that they might ask (she is referring to the examiners), I normally do not understand the direction in which the object is moving.

The evidence from the transcript indicates that the visual representation had some positive impact on learning. The learner indicated that she had experienced difficulties in the past; however her experience with the visual representation had helped to overcome learning difficulties with regards to direction.

Other examples of learners who had learning difficulties relating to direction and algebraic problem solving benefitted from the visual representations are expressed through the following interview transcripts:

Transcript 1:

Researcher : Are the pictures useful in helping you to understand the activity and momentum?

Delia : Yes it is helping me, by looking at the picture I can see the direction of the two objects, like when they collide and like when they move apart and so on.

Transcript 2:

Researcher : Are the pictures useful in helping you to understand the activity and momentum?

Sipho : When you are calculating it is easier to place the positive and the negative signs because it becomes difficult in words when they say one object goes east and the other goes west, so if you see them dramatically then it makes it easier to put signs and calculate.

The above transcript suggests that the visual representation could have had a positive impact on the conceptual understanding and of the calculations. In relation to the usefulness of the visual representation (refer to Table 5.4.1) all the learners indicated that the visual representation contributed to lessen their difficulties associated with the learning of conservation of linear momentum. All the learners were positive about the impact the pictures had on their learning (refer to the learner's verbal responses regarding the usefulness of the visual representation in Table 5.4.1).

Although the lesson initially intended on focusing on the set of pictures and the photographs, there was no time left in the lesson to reflect on the photographs hence the analysis does not reflect on the photographs (refer to Appendix S).

5.5 Analysis of classroom observation

During the observation of the lesson, I collected data in two forms. I completed an observation sheet for the first 20 minutes of the lesson (refer to Appendix P). In addition, I also took general notes on how the lesson had progressed. I also audio recorded the teacher as he taught the lesson. My reason for this was to ensure that I had not missed out on any

significant verbal interaction in the class during my observation. The general notes provided a very brief summary of what transpired during the lesson (refer to Appendix Q).

5.5.1 Lesson summary

The teacher started the lesson by introducing the lesson topic. At the onset the teacher acknowledged that the learners had already encountered the topic of conservation of momentum³. He proceeded by asking learners to recall the conservation of momentum law. One of the learners responded positively in terms of defining the law of conservation of momentum. The teacher followed up on the learner's definition by emphasising the word "isolated" and what it meant. He then proceeded to discuss the conservation of momentum equation with respect to elastic and inelastic collisions.

The next stage of the lesson involved the teacher introducing the visual representations to the learners. Instead of dividing the learners into groups, the teacher asked the learners sitting on the same work table to work together as a group. The teacher then handed out the visuals and proceeded to give instructions to the learners. He asked them to look at each scenario and in the group discuss what they observed in terms of whether linear momentum was conserved at each instant of the motion. They were meant to verify this through calculation, using the conservation of momentum equation. The mass and velocity at each stage was given in the table which the learners were asked to use. He then asked the learners to start with the activity. The activity involved the learners going through each scenario and calculating the combined momentum of the two objects represented at each instant.

During the first ten minutes of the lesson observation, I found it difficult to establish whether the learners had any learning difficulties since the lesson was initially dominated by the teacher. On the two occasions (refer to learner responses in observation sheet – Appendix P) when he involved the learners, only two of the learners from the class were able to respond to his questions. The learners were tense and extremely passive during this stage of the lesson as one would expect when the lesson is teacher-centred. This atmosphere could also have been as a result of the observer effect; a stranger was in their classroom observing them (Opie, 2004).

³ Momentum and law of conservation of momentum discussed in the lesson by the teacher is in reference to only linear systems

The atmosphere of the class however changed, as soon as the visual representations were handed out. The learners started to become more animated and their participation level increased tremendously. This stage of the lesson was most fruitful from a data analysis perspective. Learners were initially confused with the teacher's instruction and became vocal in this regard. The teacher did attempt to code switch (refer to observation sheet Appendix P) but for some particular reason, he continued in English. Once again the observer effect might have been the reason. The teacher felt the need to continue in English as a result of a stranger (who was not proficient in the local language) being in the classroom observing him.

As the activity stage progressed, the learners started to play a more active role and one could see the sudden shift as the lesson became more learner-centred. My observation had also reflected that many of the learners started to figure out the diagrams by themselves. One could sense that the learners were starting to gain clarity about the conservation of momentum.

5.6 Analysis of teacher interview

The following categories were derived from the teacher interview schedule (refer to Appendix F) and were used to analyse the teacher interview: “purpose of using visual representations”, “usefulness as a teaching strategy” and “classroom language”. First the audio recorded footage was transcribed. The next step involved entering of the quoted verbatim under the above categories.

The interview took place the following day after the lesson. During the interview, the teacher gave the impression that he had a very good relationship with his learners. The interview transcript indicates that he knows his learners well and seems to fully understand some of their learning problems. These impressions of the teacher were also verified when I sat through his lesson.

5.6.1 Classroom language

The teacher indicated that he teaches in a multilingual class using English as the primary medium of instruction and code switches with IsiZulu and Setswana. The teacher also felt that the learners were not proficient in the language of instruction. Despite this, he felt

compelled to use English citing reasons that the terminology in physical science does not appear in the local indigenous languages. The following transcript represents an excerpt of the interview:

- Researcher* : Okay so from your perspective would you say that your learners are proficient in English the language of instruction? Yes or no?
- Teacher* : Its no...er only few of them. The answer should be no...not all of them.
- Researcher* : What is the reason for using English as the medium of instruction if the learners are not understanding properly in English.
Why do you use English?
- Teacher* : I think the physical science terms are not found in African languages and that could be the reason why we use English.
- Researcher* : And the textbooks?
- Teacher* : Also the textbooks are in English.

The interview transcript also reflects that the teacher was concerned about English being used as a medium of instruction since he expressed that his learner's were not completely proficient in the language of instruction. Despite his concerns he felt that he was compelled to teach in English.

5.6.2 Purpose and usefulness of the visual representations as a teaching strategy

The teacher expressed the opinion that the use of visuals in teaching can be used to help learners to improve their understanding in sections of work in physical science where the learning content is abstract.

During the interview, the teacher admitted to not using much visual representation during his teaching. The teacher expressed that time limitation was the reason for him not using visuals in his teaching. The teacher also explained that when called upon to use visual representations, he would opt for pictures, diagrams and DVDs.

- Researcher* : In terms of visual representation strategies in teaching, how would you go about explaining a very abstract topic to your learners?

- Teacher* : I think I would prefer to use DVDs. I would also prefer to use photos or charts so that they can be able to understand the abstract topic.
- Researcher* : What type of resources and facilities you have in your school that is available for teaching and using these visual aids?
- Teacher* : We do have a laboratory even though it is not fully equipped...not TV as well.
- Researcher* : Which of the following do you use during your teaching, diagrams pictures, models, simulations, do you try to use them at any time?
- Teacher* : To tell you the truth, I do not use them often because of the time but the diagrams showing them and charts, that's what I use.

When asked about his impressions on how the visual representation had impacted on the learners, he mentioned that “they were very impressed”. He felt that the pictures and photographs simplified concepts and made it easier for the learners to follow.

His view was that the visual representations had created a positive impact on learning during the lesson. In terms of learning difficulties, the teacher believes that some of these difficulties are as a result of language proficiency. When asked about whether visual representations can help in second language learning, the teacher responded positively.

5.7 Chapter Summary

In this chapter the strategy used to analyse the data has first been explained for the learner's questionnaire, learner's interview, teacher's interview and observation of the lesson. The results have been presented and analysed under each method: the learner's questionnaire, learner's interview, the teacher's interview and the observation of the lesson.

In the next chapter, the synthesis of the findings from all the data collecting instruments will be discussed with the aim of providing a conclusion to the study.

CHAPTER 6 - GENERAL DISCUSSION & CONCLUSION

6.1 Introduction

The study was undertaken to determine how visual representation can be used to improve the learning of conservation of linear momentum. The language of instruction has also been highlighted, in relevant research, as a possible hurdle that might have an adverse impact on the learning process. In the context of the study, the objective was summarised in the following two research questions:

1. Does the use of visual representation in the form of pictures and photographs, help to promote better conceptual understanding in physical science?
2. How do these visualisation strategies help second language learners in bridging the gap in conceptual understanding due to language difficulties?

The data for the study was collected in the form of a learner's questionnaire, learner's interview, teacher's interview and observation of the lesson based on the use of the visual representations. The data was presented and analysed. In this chapter, trends from all the data collected in order to draw conclusions in relation to the research questions are brought out. On the basis of these, recommendations and implications of the study are considered.

6.2 Summary of trends from the data

A synthesis of the findings highlights trends or regularities that surfaced during the analysis. Synthesis would enable the researcher to look for links between the various data sources in relation to the research question. The synthesis is discussed according to each research question.

6.2.1 Did the visual representation help to promote better conceptual understanding amongst the learners?

The data received from both the teacher and the learners indicated that there were many difficulties that the learners had encountered during the teaching and learning of momentum prior to the lesson involving the use of the visual representation. The data so far discussed

from the questionnaires, and the learner's interviews highlighted specific learning difficulties that the learners had encountered from their past experience with conservation of linear momentum. All except two of the learners had experienced some type of learning problem. As mentioned earlier, learning difficulties relating to the interpretation of the direction of motion into the conservation of linear momentum equation seemed to be the most difficult concept for the learners. The lack of conceptual understanding in this regard seems to be a common trend that was highlighted by the data from the both the questionnaires and the interviews.

The problem with conceptual understanding is that the learners are often unable to physically visualise an object's loss or gain in momentum since it is linked with time. This study has shown that if they are able to physically visualise this time difference in the form of a sequence of pictures, then they would be in a better position to understand that momentum is conserved by one object losing energy which is gained by the other.

In terms of conceptual understanding, this study also acknowledged that there is a lack of understanding in respect to the vector nature of motion in relation to momentum. This conceptual difficulty has been highlighted and explained earlier (section 2.2) in relation to teaching pedagogy. Teachers need to come up with more creative ways of teaching in order to alleviate this problem (Bryce & MacMillan, 2009). Since the actual objective of this study served to look at creative ways to address conservation of linear momentum as a problem, the use of the visual representation has come close to fulfilling this purpose.

The visual representation in this study represented the physical interaction of objects over a period of time and indicated how they actually bump against each other, what happens at contact and after contact, as well as the messiness of the collision in relation to energy loss. Through the interviews, some of the learners had indicated that the visual representation had provided them with a means of clarifying the nature of elastic and inelastic collisions. Actually when the visual representation was utilised, all the relevant data supported the fact that the visual representation had some positive impact on the learning process.

The visual representation had apparently created more stimulating and dynamic interactions between the learners themselves and with their teacher. The data from the interviews especially, indicated that the visual representations had created a new sense of

confidence within the learners. The learners became more assertive and less reliant on the teacher as they worked through the activity. This served to enable a suggestion that the visual representation had helped some of the learners in overcoming their learning difficulties hence promoting better conceptual understanding.

However, in terms of measuring how the visual representation had promoted better conceptual understanding amongst the learners, the design of this study was such that it could not be ascertained whether the learners' understanding had improved.

6.2.2 Did the visual representation have an impact on second language learning?

Again, by design of this study it was difficult to find any links between the learner's data and the teacher's data relating to whether the visual representations had helped second language learners specifically. In the analysis of the learner's data, there was not a single learner who had attributed their learning difficulties and lack of conceptual understanding to language problems. The teacher's data on the other hand indicated that most of the learning problems that are experienced in his class are as a result of the learner's poor language proficiency in English. This claim by the teacher could however be based on teacher's unawareness of the functional value of words or difference between technical and non technical words used in science (Oyoo, 2009). Learner difficulties can also be attributed to these difficulties with technical words which does not necessarily relate to classroom language proficiency (Oyoo, 2007).

The evidence from the data sources, however, does reveal that there are language problems relating to lack of understanding as a result of language. Although the learners do not openly mention this, some of their transcripts indicate that the pictures in the visual representation had helped in their understanding and would benefit them in their solving of "word problems". Their difficulty with "word problems" could be a consequence of either the difficulty of the content or the difficulty as a result of language.

Only the observation data and the teacher's data gave some indication that the visual representation had helped these learner participants. These findings support the use of visual representation in teaching the conservation of linear momentum since it had a positive impact on their learning. These results however are inconclusive in terms of making a generalisation

in relation to whether the use of visualisation as a teaching strategy can alleviate learning problems as a result of second language learning.

Despite the lack of concrete evidence in this study to support the study's proposed view that visual representation can help second language learners, the use of more visual representations can be very beneficial to alleviating some of these learning difficulties. Visual representations will thus be used as "additional communication tool" in clarifying content especially in second language learning (Mammino, 2008, p. 162).

6.3 Implications

The results of the study suggest that the visual approach to teaching should not replace the traditional teaching methods that have relied mostly on verbal transmission (Gilbert, 2007). The implication is that the visual approach to teaching would serve as a means of enhancing conceptual understanding and helping learners to come to terms with some of the learning difficulties that they experience because of the problems they have with the language of instruction.

The results of the study supports the notion that the visual approach of representing science can be beneficial since it allows learners to relate better to concepts that are deemed abstract or invisible for the learners to interpret. The visual representation can be used as a means to facilitate better mental conception and visual imagery within the learners. The series of pictures used in the study served the purpose of trying to help learners in developing a mental model of the sequence of events taking place before and after two objects collide. This objective was met to a certain extent since the results revealed that some of the learners felt that they could now mentally visualise these sequence of events occurring during the conservation of linear momentum.

This revelation from this study therefore suggests a need for more research into how the visual mode of teaching can contribute to learners developing proper mental models of scientific concepts. This need is strengthened by the fact that as designed, the results in this study did not indicate a direct correlation between the usefulness of the visual representation in addressing difficulties relating to second language learning.

6.4 Recommendations

Part of the problem is that the learners are not exposed regularly to the visual mode of teaching since there are inadequate media resources available for a teacher to utilize especially in rural areas and urban townships schools where there are mainly second language learners (Mammino, 2008; Ramnarain, 2010).

In order for visual representations to be used as a communicative tool during the teaching of science, firstly educational authorities needs to address the issue of the lack of resources that prevents learners from being exposed to more visual modes of teaching. Secondly, the teaching pedagogy must be improved. The use of visualisation when learners are thinking about concepts must be promoted by teachers, i.e. Teachers need to introduce proactive activities that may be able to allow learners to develop visual skills. The introduction of the visual representation depicting pictures of real situations is therefore a teaching strategy that is aimed at helping learners to develop visual skills and ultimately develop a positive attitude to learning.

6.5 Concluding remarks

As a novice researcher, I embarked on the study with much trepidation since I was uncertain as to whether I would succeed in fulfilling my research obligations. Despite being overwhelmed, my desire to make an innovative and meaningful contribution to the field of physical science education had motivated me to complete the study. If the study were to be conducted again, one of the aspects of the study that I would improve on is the capturing of data. It was difficult to observe the class activity while at the same time trying to conduct the learner interviews. The use of video recording could be used to this effect. The measuring of conceptual understanding is also an area that could be improved on. The use of a pre-test and post-test (Opie, 2004) would provide more concrete evidence with regard to measuring whether the conceptual understanding in conservation of linear momentum had improved among the learner participants. Lastly the use of more sets of learner sample groups and more teacher participants would also be desirable.

Visualisation in science education represents an uncharted area of research in South Africa. The need to explore new ways to represent science concepts in a meaningful way to

both first and second language learners should become a priority if the objective is to create a truly scientifically literate society.

APPENDIX A : Ethics clearance

Wits School of Education

27 St Andrews Road, Parktown, Johannesburg, 2193 • Private Bag 3, Wits 2050, South Africa
Tel: +27 11 717-3007 • Fax: +27 11 717-3009 • E-mail: enquiries@educ.wits.ac.za • Website: www.wits.ac.za



STUDENT NUMBER: 399499
Protocols: 2010ECE44C

29 July 2010

Mr. Gonaseagran Naidoo
8 Apiesdoring Avenue
GLEN MARIAS ext 1
1619

Dear Mr. Naidoo

Application for Ethics Clearance: Master of Science

I have a pleasure in advising you that the Ethics Committee in Education of the Faculty of Humanities, acting on behalf of the Senate has agreed to approve your application for ethics clearance submitted for your proposal entitled:

The use of visual representation as a teaching strategy in Physical Science classroom.

The Protocol Number above should be submitted to the Graduate Studies in Education Committee upon submission of your final research report.

Yours sincerely


Matsie Mabeta
Wits School of Education

Cc Supervisor: Dr. S Oyoo (via email)

APPENDIX B : Approval Letter From Gauteng Department of Education



UMnyango WezeMfundo
Department of Education

Lefapha la Thuto
Departement van Onderwys

Enquiries: Nomvula Ubisi (011)3550488

Date:	10 th May 2010
Name of Researcher:	Naidoo Gonasegran
Address of Researcher:	No. 8 Apiesdoring Avenue
	Glen Marais Ext 1
	Kempton Park
Telephone Number:	0119723691/0834157743
Fax Number:	0116142527
Research Topic:	The Use of Visual Representation as a Teaching Strategy in Physical Science Classrooms
Number and type of schools:	1 Secondary School
District/s/HO	Ekurhuleni East

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

Permission has been granted to proceed with the above study subject to the conditions listed below being met, and may be withdrawn should any of these conditions be flouted:

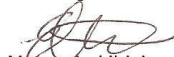
- 1. The District/Head Office Senior Manager/s concerned must be presented with a copy of this letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.*
- 2. The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.*
- 3. A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s have been granted permission from the Gauteng Department of Education to conduct the research study.*

Office of the Chief Director: Information and Knowledge Management
Room 501, 111 Commissioner Street, Johannesburg, 2000 P.O.Box 7710, Johannesburg, 2000
Tel: (011) 355-0809 Fax: (011) 355-0734

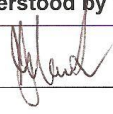
4. A letter / document that outlines the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.
5. The Researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, and chairpersons of the SGBs, teachers and learners involved. Persons who offer their co-operation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.
6. Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.
7. Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year.
8. Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.
9. It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.
10. The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.
11. The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.
12. On completion of the study the researcher must supply the Director: Knowledge Management & Research with one Hard Cover bound and one Ring bound copy of the final, approved research report. The researcher would also provide the said manager with an electronic copy of the research abstract/summary and/or annotation.
13. The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned.
14. Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards



Nomvula Ubisi
DEPUTY CHIEF EDUCATION SPECIALIST: RESEARCH

The contents of this letter has been read and understood by the researcher.	
Signature of Researcher:	
Date: 10/05/2010	

APPENDIX C : Letter requesting for Permission to Conduct Research

Mr G Naidoo
8 Apiesdoring Avenue
Glen Marais Ext 1
1619

13 May 2010

The principal
Tembisa Secondary School

Sir

Re : Permission to conduct masters research study at your school

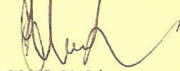
I am currently a masters student enrolled at the university of Witwatersrand. As part of the requirements for completing my studies, I am required to submit a research project. The topic of the study is titled "The use of visual representation as a teaching strategy in the physical science classroom".

I would like to use your school as my research site. To this end, I would appreciate if I could meet with you in person to present my study to you. The objective of the study is to determine whether a teaching strategy that incorporates visual learning would help in promoting better conceptual understanding in physical science. The study has implications on how physical science is currently being taught at schools from the perspective of improving the teaching and learning of physical science.

The study will require for me to use two of your senior science teachers and two classes of grade 11 learners. The teachers would be required to teach a particular lesson to their learners. My role as the researcher is to observe the lesson and collect data. The data that will be collected are in the form of a learner's questionnaire, learner's interview, teacher's interview and observation of the lesson. All the research participants would obviously be briefed and they would also be required to complete necessary consent forms.

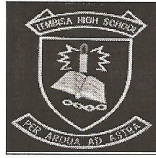
The study will take place during one of the science periods. I assure you that there will be minimum disruption to teaching time.

Thank You



Mr G Naidoo

APPENDIX D : Letter of Permission granted



TEMBISA SECONDARY SCHOOL

GAUTENG DEPARTMENT OF EDUCATION

REG: 261305

PO Box 38, TEMBISA, 1628

TEL: 011 926 2365

FAX: 011 926 8534

E-mail, tembisahigh@telkomsa.net

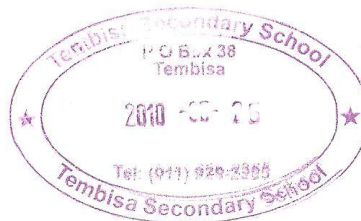
25 May 2010

Dear Mr Naidoo

In my capacity as headmaster, I hereby grant you permission to conduct your research at Tembisa Secondary School. Please note that you are welcome to have access to the school and the relevant teachers and learners upon which your research is based on. Access is however only granted during our stipulated school times. It has also been noted through our meeting that you would respect our teaching times and not necessarily infringe on them.

Kind Regards

Mr N:M Letsoalo



APPENDIX E : Learner's questionnaire

Questionnaire for the Learners

INSTRUCTIONS

Do not write down your name or any other personal details. If you do not want to answer a particular question, you are welcome to leave it out and proceed to the next question. The information that you are providing will be confidential, therefore you should not discuss or show your answers to your classmates. You must complete the questionnaire by yourself.

Language of Instruction

1. What is your home language/s?
2. What languages do you and your classmates use during your physical science lessons?
3. What languages do your teachers use during the lessons?
4. What language are you most comfortable with in the learning of Physical Science?
5. How do you feel when your teacher uses English during the lesson?

Learner's response to the Lesson

6. Do you enjoy learning physical science?

--
7. How would you compare it to your other school subjects?

--
8. What are some of the things that you do not understand in the subject?

Continued on next page

9. The first time that you were taught conservation of momentum, what aspects of the work did you find difficult to understand?

10. Did the use of the pictures in this particular lesson help you in any way? Explain your choice of answer.

11. What did you like and dislike about using the pictures in the lesson?

Likes	
Dislikes	

12. Were you able to relate the concepts of momentum to the set of photographs? Explain

13. In future will you like to have more of your lessons taught in this way? Explain.

Thank You for your Participation

APPENDIX F : Teacher's interview schedule

Interview Schedule for Teacher

Teacher's Background

1. Do you have a professional teaching qualification? Please specify.
2. What is your area of specialization?
3. How many years of teaching experience do you have?
4. What subjects are you currently teaching at your school?

Language of Instruction

5. What is your home language?
6. What is the language of instruction that you are currently using during your teaching of physical science?
7. What is the language of instruction that you would prefer teaching in and why?
8. How do your learners respond when you explain in English?
9. From your perspective are your learners proficient in the language of instruction?

Use of visual strategies in teaching

10. How would you go about explaining a very abstract topic to them?
11. What facilities are available at your school for science teaching?
12. Which of the following do you use during your teaching?
Diagrams/Pictures/Models/Simulations
13. How often do you use any of the above during your teaching?
14. Have you had any professional training with regards to using certain visual representations?
15. What impact does the use of these diagrams, pictures, models or simulations have on your teaching?

Learner's understanding

16. How do you think the learners responded to the visual representation during the lesson? Give reasons.

END OF INTERVIEW

Thank You for your Participation

APPENDIX G : Learner's Interview

UNSTRUCTURED QUESTIONS FOR LEARNERS:

1. How are you coping with the classroom activity?
2. What is it about momentum that is difficult for you to understand?
3. Are the pictures and photographs useful in helping with your understanding of the work?
4. In what way are the pictures useful?

APPENDIX H : Observation Sheet (adapted from Opie, 2004)

Key

Category (Teacher)	Code No.	Category (Learner)	Code No.
- questioning	1	- positive response to teacher	1
- explaining facts and content	2	- negative response to teacher	2
- ability to arouse interest and curiosity	3	- pupil talk – self initiation	3
- probe further understanding	4	- confused	4
- uses ideas of students	5	- asks questions	5
- intervenes to help the learners	6	- code switching during there responses	6
- no required to assist learners	7		
- resorts to code switch during explanations	8		

Time (min)	Teacher	Learners
5		
10		
15		
20		
25		
30		
35		
40		
45		

Teacher' Responses/Comments	Learner's Responses/Comments

APPENDIX I : Participant information sheet

PARTICIPANT INFORMATION SHEET (Teacher)

As part of fulfilling my master's in science degree, I have undertaken a research project and would like to invite you to be a participant in my research. My research project is entitled, *The use of Visual Representation as a teaching strategy in the Physical Science classroom*. My name is Gonasegran Naidoo and I am registered as a part-time student at the University of Witwatersrand. The purpose of my research project is to determine how teachers can improve their teaching and their teaching methods in the physical science classroom. During my research I will ask the teachers involved to use a particular teaching method during one of their lessons. I would try to determine how the new teaching method has affected the learner's understanding in physical science.

As a participant you are required to participate in the lesson itself in the capacity of a teacher. Your participation will be on a voluntary basis and you will be free to opt out of the research at any stage and are under no obligation what so ever. The participants will also not be subjected to any physical danger during the research. The duration of the research lesson would be approximately forty five minutes after which the learners will be invited to complete a questionnaire. This would take approximately fifteen minutes and the total time of the entire exercise will be approximately sixty minutes.

The participant teacher would be invited to participate in an interview that would also take approximately fifteen minutes. The interview would take place after the lesson at another time when the participant is available. I will also be present in person and will be making observations during the lesson. Please do not feel threatened or uncomfortable as I am merely there to observe the lesson in order to obtain data for my research. The information that I get from the observations, interviews and questionnaires will be used strictly for my research purposes only and will not be shared with anyone else other than my supervisor. The information that I receive will be treated with sensitivity and confidentiality.

If you have any queries regarding the research, you are welcome to contact me. My email address is naidooo@yahoo.com and my phone numbers are 083 415 7743/011 614 1938. You are also welcome to contact the supervisor of my project, Dr S Oyoo, at 011 717 3263. Please find attached the necessary consent forms that you are requested to complete. Thank you for your participation.

APPENDIX J : Participant information sheet

PARTICIPANT INFORMATION SHEET (Learner)

As part of fulfilling my master's in science degree, I have undertaken a research project and would like to invite you to be a participant in my research. My research project is entitled, *The use of Visual Representation as a teaching strategy in the Physical Science classroom*. My name is Gonasegran Naidoo and I am registered as a part-time student at the University of Witwatersrand. The purpose of my research project is to determine how teachers can improve their teaching and their teaching methods in the physical science classroom. During my research I will ask the teachers involved to use a particular teaching method during one of their lessons. I would try to determine how the new teaching method has affected the learner's understanding in physical science.

As a participant you are required to participate in the lesson itself as part of the learners in the classroom. Your participation will be on a voluntary basis and you will be free to opt out of the research at any stage and are under no obligation what so ever. The participants will also not be subjected to any physical danger during the research. The duration of the research lesson would be approximately forty five minutes after which you will be invited to complete a questionnaire. This would take approximately fifteen minutes and the total time of the entire exercise will be approximately sixty minutes.

I will also be present in person and will be making observations during the lesson. Please do not feel threatened or uncomfortable as I am merely there to observe the lesson in order to obtain data for my research. The information that I get from the observations, interviews and questionnaires will be used strictly for my research purposes only and will not be shared with anyone else other than my supervisor. The information that I receive will be treated with sensitivity and confidentiality.

If you have any queries regarding the research, you are welcome to contact me. My email address is naidooo@yahoo.com and my phone numbers are 083 415 7743/011 614 1938. You are also welcome to contact the supervisor of my project, Dr S Oyoo, at 011 717 3263. Please find attached the necessary consent forms that you are requested to complete. Thank you for your participation.

Parent Consent Form

I, _____, the parent/guardian of
_____, hereby give permission for my child/ward to participate
in the research project. I fully acknowledge that my child's/ward's participation will be in
the form of taking part in a classroom lesson as a learner. I acknowledge that the research
would be conducted during school hours and my child will not be subjected to any form of
danger during the research. The results of the research will be treated with confidentiality.

Name and surname of parent/guardian

Signature of parent/guardian

APPENDIX L :

Interview Consent Form

I hereby consent to participate as an interviewee in the research project. As a participant I fully acknowledge that the results of the interview will be used for this particular research project only. The data obtained from the interview would be treated with confidentiality and anonymity.

Name and surname of Interviewee

Signature of Interviewee

APPENDIX M :

Audio Recording Consent Form

I hereby consent to allowing the interviewer Mr. G Naidoo to audio record the interview. I fully acknowledge that the interview transcripts will be used for this particular research project only and will be not used for any other purpose. The data obtained from the interview would be treated with confidentiality and anonymity.

Name and surname

Signature of participant

APPENDIX N :

Minor Assent Form

I, _____, hereby consent to be a participant learner in a classroom lesson that forms part of a research project. My participation will be purely on a voluntary basis and I have the right to withdraw from the project at any given time. I acknowledge that my input during the lesson would be used only for the purpose of the research and would be treated with anonymity and confidentiality.

Name and surname of Participant

Signature of Participant

APPENDIX O : Sample of completed consent form

Interview Consent Form

I hereby consent to participate as an interviewee in the research project. As a participant I fully acknowledge that the results of the interview will be used for this particular research project only. The data obtained from the interview would be treated with confidentiality and anonymity.

Lucas Mosane
Name and surname of Interviewee

Lucas
Signature of Interviewee

APPENDIX P : Completed Observation sheet

OBSERVATION SHEET (adapted from Opie, 2004)

Key

Category (Teacher)	Code No.	Category (Learner)	Code No.
- questioning	1	- positive response to teacher	1
- explaining facts and content	2	- negative response to teacher	2
- ability to arouse interest and curiosity	3	- pupil talk – self initiation	3
- probe further understanding	4	- confused	4
- uses ideas of students	5	- asks questions	5
- intervenes to help the learners	6	- code switching during there responses	6
- no required to assist learners	7		
- resorts to code switch during explanations	8		

Time (min)	Teacher	Learners
5	1, 2, 2, 1, 3	1
10	4, 4, 5, 6	1
15	8, 2, 1, 6	4, 5
20	1	
25	{Lesson activity - learners worked on activity}	
30		
35		
40		
45		

learners confused about instruction

Teacher's Responses/Comments	Learner's Responses/Comments
code switched once - questions in relation to Δ heli = Δ Pafier - state law - explaining isolated system.	- 2 correct answers to questions! - very positive during lesson.

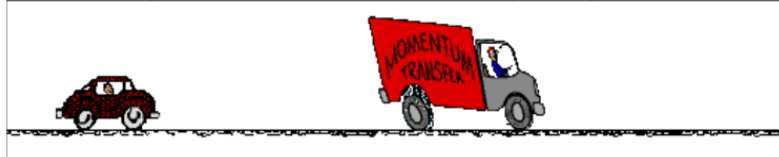
APPENDIX Q : Observation notes

- ① Teacher introduces topic
- ② Asks for definition
- ③ Elicits positive answer (from learner)
- ④ Teacher stresses on "isolated"
- ⑤ Discusses the equation
 - mentions that usually ^{in reality} momentum is not conserved due to ¹ loss of energy in heat & sound
- ⑥ Asks learners
- ⑦ Learner answers (positively about elastic & inelastic)
- ⑧ Teacher talks about $\perp$ diff. b/w
 - elastic - no loss of KE conserved
 - inelastic - not conserved.
- ⑨ After intro teacher proceeds with discussion using the pictures
 - discusses 1st scenario & elaborates on scenario
- ⑩ Gives instructions to do all instructions.
- ⑪ Learners confused about what to do
- ⑫ Teacher has to repeat by doing example one.

APPENDIX R

Scenario 1

Car			Truck		
mass (kg)	1000		mass (kg)	3000	
vel. (m/s)	20.0		vel. (m/s)	0.0	
mom. (kg m/s)	20 000		mom. (kg m/s)	0	



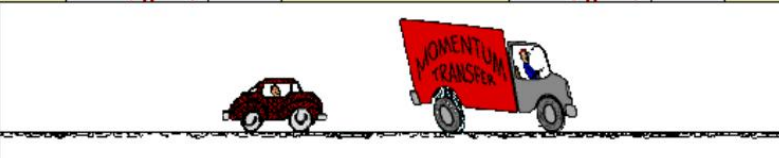
Car			Truck		
mass (kg)	1000		mass (kg)	3000	
vel. (m/s)	20.0		vel. (m/s)	0.0	
mom. (kg m/s)	20 000		mom. (kg m/s)	0	



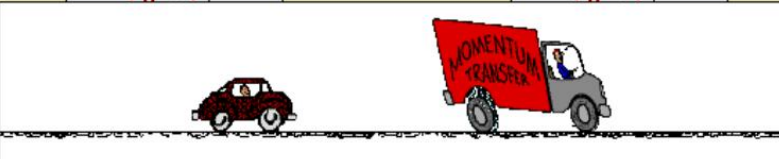
Car			Truck		
mass (kg)	1000		mass (kg)	3000	
vel. (m/s)	20.0		vel. (m/s)	0.0	
mom. (kg m/s)	20 000		mom. (kg m/s)	0	



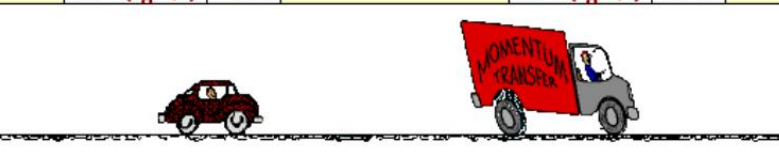
Car			Truck		
mass (kg)	1000		mass (kg)	3000	
vel. (m/s)	-10.0		vel. (m/s)	10.0	
mom. (kg m/s)	-10 000		mom. (kg m/s)	30 000	



Car			Truck		
mass (kg)	1000		mass (kg)	3000	
vel. (m/s)	-10.0		vel. (m/s)	10.0	
mom. (kg m/s)	-10 000		mom. (kg m/s)	30 000	



Car			Truck		
mass (kg)	1000		mass (kg)	3000	
vel. (m/s)	-10.0		vel. (m/s)	10.0	
mom. (kg m/s)	-10 000		mom. (kg m/s)	30 000	



APPENDIX R

Scenario 2

Car		Truck	
mass (kg)	1000	mass (kg)	3000
vel. (m/s)	20.0	vel. (m/s)	-20.0
mom. (kg m/s)	20 000	mom. (kg m/s)	-60 000



Car		Truck	
mass (kg)	1000	mass (kg)	3000
vel. (m/s)	20.0	vel. (m/s)	-20.0
mom. (kg m/s)	20 000	mom. (kg m/s)	-60 000



Car		Truck	
mass (kg)	1000	mass (kg)	3000
vel. (m/s)	20.0	vel. (m/s)	-20.0
mom. (kg m/s)	20 000	mom. (kg m/s)	-60 000



Car		Truck	
mass (kg)	1000	mass (kg)	3000
vel. (m/s)	-40.0	vel. (m/s)	0.0
mom. (kg m/s)	-40 000	mom. (kg m/s)	0



Car		Truck	
mass (kg)	1000	mass (kg)	3000
vel. (m/s)	-40.0	vel. (m/s)	0.0
mom. (kg m/s)	-40 000	mom. (kg m/s)	0



APPENDIX R

Scenario 3

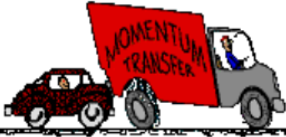
Car		Truck	
mass (kg)	1000	mass (kg)	3000
vel. (m/s)	20.0	vel. (m/s)	0.0
mom. (kg m/s)	20 000	mom. (kg m/s)	0



Car		Truck	
mass (kg)	1000	mass (kg)	3000
vel. (m/s)	20.0	vel. (m/s)	0.0
mom. (kg m/s)	20 000	mom. (kg m/s)	0



Car		Truck	
mass (kg)	1000	mass (kg)	3000
vel. (m/s)	5.0	vel. (m/s)	5.0
mom. (kg m/s)	5 000	mom. (kg m/s)	15 000



Car		Truck	
mass (kg)	1000	mass (kg)	3000
vel. (m/s)	5.0	vel. (m/s)	5.0
mom. (kg m/s)	5 000	mom. (kg m/s)	15 000



Car		Truck	
mass (kg)	1000	mass (kg)	3000
vel. (m/s)	5.0	vel. (m/s)	5.0
mom. (kg m/s)	5 000	mom. (kg m/s)	15 000



APPENDIX R
Scenario 4

Car		Truck	
mass (kg)	1000	mass (kg)	3000
vel. (m/s)	20.0	vel. (m/s)	-20.0
mom. (kg m/s)	20 000	mom. (kg m/s)	-60 000

Car		Truck	
mass (kg)	1000	mass (kg)	3000
vel. (m/s)	20.0	vel. (m/s)	-20.0
mom. (kg m/s)	20 000	mom. (kg m/s)	-60 000

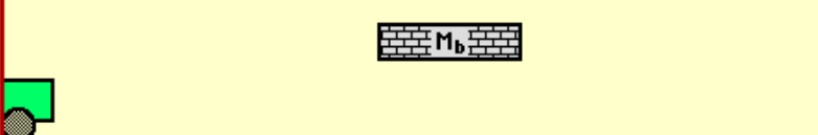
Car		Truck	
mass (kg)	1000	mass (kg)	3000
vel. (m/s)	-10.0	vel. (m/s)	-10.0
mom. (kg m/s)	-10 000	mom. (kg m/s)	-30 000

Car		Truck	
mass (kg)	1000	mass (kg)	3000
vel. (m/s)	-10.0	vel. (m/s)	-10.0
mom. (kg m/s)	-10 000	mom. (kg m/s)	-30 000

Car		Truck	
mass (kg)	1000	mass (kg)	3000
vel. (m/s)	-10.0	vel. (m/s)	-10.0
mom. (kg m/s)	-10 000	mom. (kg m/s)	-30 000

APPENDIX R
Scenario 5

Cart		Dropped Brick	
Mass (kg)	1.0	Mass (kg)	2.0
Vel. (cm/s)	60.0	Vel. (cm/s)	0.0
Mom. (kg cm/s)	60.0	Mom. (kg cm/s)	0



Cart		Dropped Brick	
Mass (kg)	1.0	Mass (kg)	2.0
Vel. (cm/s)	60.0	Vel. (cm/s)	0.0
Mom. (kg cm/s)	60.0	Mom. (kg cm/s)	0



Cart		Dropped Brick	
Mass (kg)	1.0	Mass (kg)	2.0
Vel. (cm/s)	20.0	Vel. (cm/s)	20.0
Mom. (kg cm/s)	20.0	Mom. (kg cm/s)	40.0



Cart		Dropped Brick	
Mass (kg)	1.0	Mass (kg)	2.0
Vel. (cm/s)	20.0	Vel. (cm/s)	20.0
Mom. (kg cm/s)	20.0	Mom. (kg cm/s)	40.0



Cart		Dropped Brick	
Mass (kg)	1.0	Mass (kg)	2.0
Vel. (cm/s)	20.0	Vel. (cm/s)	20.0
Mom. (kg cm/s)	20.0	Mom. (kg cm/s)	40.0



APPENDIX S



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