An investigation into how Grade 10 Physical Sciences learners make sense of resultant vectors

A thesis submitted in partial fulfilment of the requirements for the degree

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By

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DECLARATION

I declare that the work contained in this thesis is my original work. It has not been previously submitted in any form for assessment or degree in any other higher education institution. All ideas, quotations and other materials used in this study derived from the work of other people have been indicated in the list of references.

Signature: ______________________ Date: 16/03/2016

ABSTRACT

The focus of this study was on how Grade 10 Physical Sciences learners make sense of resultant vectors. During my experience over more than 10 years as a Science teacher in Matatiele in the Eastern Cape Province I found that Grade 10 Physical Sciences learners consistently struggled to work with resultant vectors. Many studies have shown that learners in similar contexts are generally not doing well in Science.

An interpretive paradigm was used in this study, focusing on the individual or a specific group in a qualitative case study approach and a social constructivist perspective. The unit of analysis was on how Grade 10 Physical Sciences learners make sense of resultant vectors. A diagnostic test, observation and videotaped lessons, learners' workbooks, summative test and stimulated recall interviews were used to gather data. The data were analysed inductively using a thematic approach and in relation to the main research question: *How do Grade 10 Physical Sciences learners make sense of resultant vectors?*

The data were validated through watching the videotaped lessons with the teacher who had been observed teaching vectors. Also, transcripts of the interviews and a summary of discussions were given back to the teacher whose learners had been observed to verify the learners' responses and check for any misconceptions.

It was found that linking scientific concepts to learners' prior knowledge enabled them to learn in a relaxed and non-threatening environment. In doing so, sense making of resultant vectors was possible. The study thus recommends that teachers should be supported in their endeavours to help learners make sense of scientific concepts during teaching and learning situations. Some language related challenges that were also encountered warrant further research.

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DEDICATION

This thesis is dedicated to my wife and kids. They gave me untiring support throughout this research journey.

ACKNOWLEGDEMENTS

First of all, I would like to thank the Almighty God by whose grace I was strengthened, encouraged and so managed to go through this journey. There was a time when I wanted to give up but because His grace is sufficient for us, I managed to press on.

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To my family, wife and kids and all who were backing me, I salute you. May God richly bless you, I thank you!

To the colleagues who were there to support me in times of weariness and even despair I say Keep it up! The 'WhatsApp' group we formed gave me invaluable support. Special dedications to my colleague and home mate Lineo Ramasike who gave me the strength to sustain the strain of writing this thesis. She has really been a friend indeed!

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Lastly, I would like to thank the editor for spending his/her time reading and editing my work. I say thank you very much!

LIST OF TABLES, PICTURES AND FIGURES

TABLES:

PICTURES:

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LIST OF ABBREVIATIONS AND ACRONYMS

T2-	Teacher 2
Q-	Question
SQ-	Sub-question
DSQ 1.1-	Diagnostic test sub-question 1.1
SSQ1.1-	Summative test sub-question 1.1
L1R-	Learner one response
L2R-	Learner two response
L1- **L7**	Learners one through seven
AL-	All learners
FQ-	Follow-up question
MKO-	More knowledgeable other
CAPS-	Curriculum and assessment policy statement
DoE-	Department of Education
DBE-	Department Of Basic Education
ZPD-	Zone of proximal development

CHAPTER ONE

SITUATING THE STUDY

1.1 INTRODUCTION

The purpose of this study was to investigate how Grade 10 Physical Sciences learners make sense of the concept of the resultant vector. The research was triggered by having observed over a number of years that Physical Sciences learners were performing poorly in the subject.

In this chapter, I discuss the background of the study, its significance, the research goals and the theoretical framework which informed it.

1.2 BACKGROUND/CONTEXT

In 1995 the International Mathematics and Science Study (TIMSS) administered a test in 41 countries, in which South African learners obtained the mean score of 351, which was below the international average of 513. In the TIMSS Report of 1999 Grade 8 learners in South Africa obtained a mean score of 274, also below the international mean score of 487, with South Africa scoring the lowest after Morocco and Tunisia.

TIMSS reports from 2002 to 2011 revealed some significant improvement in South African performance. In 2002, 10, 5% of South African learners scored above 400 points while in 2011, about 24% scored above 400. However, the 13, 5% improvement in a period of 9 years, is minor compared to other participating countries. This could be due to various factors. For instance, learners struggled in those questions that needed more critical thinking and application (Poynter & Tall, 2008; Kocakulah & Kenar, 2011).

A study conducted in Nigeria by Nguyen and Meltzer (2003) found that about 42% of all the learners who were asked to draw a parallelogram of vectors could not draw it properly. Poynter and Tall (2008) noted that learners usually failed to indicate the direction of a resultant vector.

According to the South African Curriculum Assessment Policy Statement (CAPS), the Physical Sciences syllabus is divided into two sections, namely Chemistry and Physics. Mechanics is one of the topics found under Physics. It is under this topic that vectors are discussed (South Africa, DoE, 2011).

Table 1: Module 5 (Mechanics) in Grade 10 as per CAPS:

UNIT NUMBER	UNIT TITLE	SUB-TOPICS OF THE UNIT
1	Vectors and scalars	Vectors and scalars
		Properties of vectors
2	Motion in one direction	Reference frame, position, displacement, and distance
		Average speed, average velocity, acceleration
		Instantaneous speed and velocity
3	Description of motion	Describing motion in words
		Describing motion in graphs
4	Energy	Gravitational potential energy
		Kinetic energy
		Mechanical energy
		Conservation of mechanical energy

Table 1 shows the units under Mechanics and their sub-topics, most of which use vectors. Vectors are defined as physical quantities which have both magnitude and direction (Brink & Jones, 1986). A resultant vector is defined as a single vector which has the same effect as two or more vectors acting together (Knight, 2004). Some examples of vectors are force, displacement, velocity and acceleration.

According to the CAPS documents for Physical Sciences Grades 10, 11 and 12, the topic on Mechanics under which vectors fall, contributes a significant percentage of marks in the examinations as indicated in the table below,

Table 2: The weighting of Mechanics across the FET band (CAPS, DBE, 2011):

Mechanics	**Grade 10**	**Grade11**	**Grade 12**
Weighting	18,75%	16,87%	17,50%

In Grade 10, which is the grade considered in this study, the weighting of 18,75% is a considerable proportion of the total marks for Paper One of Physical Sciences.

Table 3: Weighting of prescribed content (Examination Guidelines of 2014, DoE, South Africa):

<table>
<tr><th colspan="8">Paper 1: Physics Focus</th></tr>
<tr><th>Content</th><th>Marks</th><th>Total</th><th>Duration</th><th colspan="4">Weighting of cognitive levels</th></tr>
<tr><td>Mechanics</td><td>63</td><td rowspan="4">150 marks</td><td rowspan="4">3 hours</td><td rowspan="4">15</td><td rowspan="4">35</td><td rowspan="4">40</td><td rowspan="4">10</td></tr>
<tr><td>Waves, sound and light</td><td>17</td></tr>
<tr><td>Electricity and magnetism</td><td>55</td></tr>
<tr><td>Matter and material</td><td>15</td></tr>
</table>

The table above shows the weighting of marks in Mechanics as compared to other topics. Vectors and resultant vectors contribute 63 marks of Mechanics. Bearing in mind that the Examination Guidelines of the Department of Education stipulate that prior knowledge from Grade 10 and 11 will be tested in Grade 12, the skills learned in each grade are important.

Below is the summary of skills expected from learners:

- The use of equations of motion in solving problems dealing with momentum, vertical projectile motion, work, energy and power;
- Resolving vectors into a triangle and a polygon; and
- Calculating component vectors and resultant vectors using different methods (CAPS) (DBE, 2011).

In the face of the above skills expected to be learned, learners perform poorly in Science. As a result, there is a concern by the national government and the public about the poor performance of Grade 12 learners in Physical Sciences.

For instance, the Examiners' reports have repeatedly given feedback on poor performance by Grade 12 candidates. The Examiners' reports for 2010, 2011, 2012 and 2013 (Department of Basic Education, South Africa) on the National Senior Certificate (NSC) Physical Sciences Paper One, highlighted that learners were not performing well on the topic of vectors, noting that candidates could not write the equation of forces acting on an object, $W = f\Delta x Cos\theta$. Another challenge highlighted by the reports was that the learners could not relate between the, $f_{horizontal}$ and $Cos\theta$. That is, learners tended to confuse representation of concepts using symbols.

The interpretation of symbols in Physical Sciences enables the basic understanding of concepts which should supposedly have been taught in earlier grades. For instance, the topic of force (f) is taught in Grade 9 according to CAPS (DBE, 2011). Yet, some learners get to Grade 10 still having problems in interpreting the symbols (Gabel, 1999). For another example, in Grade 10 Mathematics, trigonometric ratios are introduced which involve the angle between vectors acting together. Hence, the knowledge of trigonometric ratios is the key in calculating the resultant of vectors acting at a right angle. At this point, learners must be able to integrate what they learned in Mathematics with what they are now learning in Science.

To this end, Wood, Bruner and Ross (1976) argue that teachers should help learners to recall what they have learned in the previous grades. Integration stimulates the sense making of the next grade's knowledge.

In the context of this study, 'sense making' is when learners are able to combine prior knowledge with present knowledge to produce new knowledge (Douglas & Michael, 1990; Weick, 1993). Weick (1993) considered sense making as the concept used to bring together insights drawn from philosophy, sociology and cognitive science. Sense making also involves linking the classroom experience with learners' prior everyday knowledge (Duffy, 1995).

1.3 SIGNIFICANCE OF THE STUDY

This was a qualitative case study and its main focus was on how Grade 10 Physical Sciences learners make sense of resultant vectors. An understanding of this concept prepares Grade 10 learners for the topics in Grade 11 (vectors in two dimensions including Newton's laws of motion) and Grade 12 (momentum and impulse; work, energy and power). Considering that the research focused on the learners, it could also potentially contribute to the improvement of teachers' practice. Furthermore, it could serve as a reference for further research on this and related topics. Other beneficiaries of this study would be curriculum developers, examiners, materials developers, textbook writers as well as Physical Science educators.

1.4 RESEARCH GOAL AND RESEARCH QUESTIONS

In accordance with the aim of this study, I sought to answer the following main question:

- How do Grade 10 Physical Sciences learners make sense of resultant vectors?

The following sub–questions were used to help answer the main question:

- What prior knowledge do the Grade 10 Physical Sciences learners have on the topic of resultant vectors?

To answer this sub-question, I analysed the learners' responses to a diagnostic test. I also noted learners' responses during lesson discussions, which revealed their knowledge of resultant vectors.

- What kind of learning mediation is required to help learners make sense of the topic of resultant vectors?

The lessons were observed, videotaped and transcribed before being analysed.

- What are the challenges encountered by the Grade 10 learners in calculating resultant vectors?

This question was answered through a diagnostic test, worksheets and a summative test.

1.5 THEORETICAL FRAMEWORK

A theoretical framework provides a structure on which a research project is based (Merriam, 2002) and hence influences every aspect of the research, namely, the research problem, methodology, data analysis and interpretation. Hitchcock and Hughes (1995, p. 21) suggest that assumptions about the reality of enquiry and nature of things give rise to epistemological assumptions. It is important to consider the appropriate theory that will make the findings authentic and valid. This study was therefore informed by constructivism, that is, Piaget's cognitive constructivism and Vygotsky's theory of social constructivism and mediation of learning. Below are the discussions of the theories as they apply to this study but firstly I discuss what constructivism is.

1.5.1 Constructivism

Constructivism is based on the view that learners construct their own knowledge, strongly influenced by their prior knowledge. In this process, learners construct their own individual sense of understanding (Tobin, Tippins & Gallard, 1996). Constructivism implies that the new knowledge cannot exist outside someone's existing knowledge (von Glasersfeld, 1989; Moll, 2002). Rather, the new knowledge is linked to the existing knowledge. Essentially, constructivism implies that people construct their own understanding and knowledge of their environment through experiencing things and reflecting on those experiences.

Constructivism provides ideas on how to assist learners to construct knowledge and make sense of the world (Hodson & Hodson, 1998). Relating that to the subject of this study, learning resultant vectors involves making sense of the different concepts. This involves active involvement on the part of learners and this is central to constructivism.

The constructivist theory is thus an appropriate lens to understand the subject of learning vectors since the successful teacher will enable learners to apply their everyday knowledge when learning about resultant vectors. Additionally, the teacher will serve as a facilitator and a mediator who helps the learners to achieve their individual understanding (Bauersfeld, 1995). This study focused on Vygotsky's social constructivism and mediation of learning.

1.5.2 Cognitive constructivism

Derry (1996) defined cognitive constructivism as a general metaphorical assumption about the nature of cognition that virtually all cognitive educational researchers accept, and emphasized that it should not be regarded as a unique theoretical framework, pedagogical approach, or epistemology. Atherton (2009) defined cognitive theory as being about the individual learner understanding the world around him. As much as the topic on resultant vectors is abstract, the learners will need their individual interpretation of its concept. The learners' own rationale will thus be vital in the sense making of resultant vectors.

1.6 RESEARCH DESIGN

Research design serves as a point of departure on the journey of an inquiry (Cohen, Manion & Morrison, 2011). Planning the research includes designing the research paradigm and the approach to be followed, research sites and participants and data gathering strategies. The researcher must also take into consideration the unforeseeable aspects involved in the research (*ibid*.).

1.6.1 Research paradigm and research approach

This study was underpinned by an interpretive paradigm. The interpretive paradigm is concerned more with a specific group of people (Cohen, Manion & Morrison, 2011). In the context of this study, the interpretive paradigm helped provide some insights into how the Grade 10 Physical Sciences learners made sense of the concept on the resultant vectors.

Within the interpretive paradigm, a qualitative case study approach was employed. A case study is defined as the study of a particular event or action (Stake, 1995). A case study is usually a response to an action or an event (Adelman, Kemmis & Jenkins, 1980). A case study was appropriate for my study as it was trying to understand how Grade 10 Physical Sciences learners are struggling with the concept of the resultant vectors. A case study, as further defined by Cohen et al. (2011), is a specific instance that is frequently designed to illustrate a more general principle; the single instance is of a restricted system, for example, a learner, school or community. It provides sole examples of real people in real situations, enabling readers to comprehend ideas more obviously than by simply presenting the abstract theories or principles.

Yin (2003) too stated that the case study tries to illuminate a decision or set of decisions: why they were taken, how they were implemented, and with what result. In essence, this was a qualitative case study which focused on promoting sense making of learners' learning in everyday situations and experiences in the school science curriculum. The aim was to improve their conceptual development and sense making in Physical Sciences, in particular, of the topic of resultant vectors.

1.6.2 Research site and participants

The research participants in this study were Physical Sciences Grade 10 learners and the class consisted of about 35 learners at Komadihare Secondary School (pseudonym). So, the focus was on Grade 10 Physical Sciences learners as they were taught by their teacher while making sense of resultant vectors. Purposive sampling was used to choose learners after administering a diagnostic test to the entire class. That is, a focus group of ten learners were purposefully chosen so as to achieve a spread in their diverse abilities and so gain insight into how they made sense of the concepts of the resultant vector.

At this stage I worked together with the participating teacher from Komadihare Secondary School, to co-develop model lessons on resultant vectors. The teacher then taught the lessons to her Grade 10 learners while I observed. The observations involved videotaping the lesson presentations and the learning processes. The lesson observations provided information on how learners interacted during the learning of resultant vectors. It was particularly important to see how they related the different concepts to each other.

1.6.3 Data gathering techniques

Cohen et al. (2011) define data gathering as those techniques that are to be used in the collection of information for one's research. They emphasise that numerous techniques may be engaged, complementing each other in some instances and so validating the data. Different forms of data gathering techniques were employed to collect information. This triangulation method helped the validation of this study. The techniques used to collect data are listed below:

- Diagnostic test;
- Observations, videotaped lessons and learners' workbooks;
- Summative test;
- Semi-structured interviews;
- Focus group interviews.

1.7 DEFINITION OF KEY CONCEPTS

- Physical Sciences: is the subject and the field under which the study was conducted.
- Resultant vector: is a single vector which has the same effect as the original vectors combined together.
- Sense making: is the process whereby knowledge and learning are being internalised.
- Social constructivism: a socio-cultural theory which advances that knowledge is acquired through interactions in a social context.
- Mediation of learning: the process in which the teacher interacts with the learner in order to scaffold their intellectual development.
- Scaffolding: the assistance provided to the learners during teaching and learning activities with the aim of helping learners to make sense of the topic.
- More knowledgeable other (MKO): is the person who has more knowledge and experience about a topic, better than others do. In this case, the teacher acts as a MKO.

1.8 THESIS OUTLINE

Chapter One introduces my research topic and seeks to locate my place as a researcher in the study. Its significance is described. The research site and my research participants are identified. The data gathering techniques are outlined.

Chapter Two is a literature review examining the theoretical premise for the research on sense making during the learning of resultant vectors by Physical Sciences learners. Literature is consulted in respect of the theory that underpins the curriculum (constructivism) and also the knowledge content requirements for Grade 10 learners in respect of the topic of resultant vectors. Literature regarding sense making and prior everyday knowledge is reviewed. Finally, material on learner-talk is consulted to build familiarity with that concept.

Chapter Three describes the methodological framework that directed the research processes. It gives the reasons for selecting the approach adopted to address the research goals and questions and it explains my own role as a researcher in the research process. It also describes the research process as well as how data are collected and analysed. It concludes with a discussion of research trustworthiness, validity and ethical considerations.

In **Chapter Four**, I present and discuss the data gathered, unpacking the processes of data collection and the techniques used.

Chapter Five contains the report on the data collected and present the data analysis. The discussion about the whole research process and the findings are also presented here.

Chapter Six contains concluding recommendations and critical reflections. It starts with a summary of the research process and then highlights a few critical remarks in respect of my study. It briefly contextualizes my research goal within the rationale for embarking on this research and then suggests a few recommendations for future research.

1.9 CONCLUDING REMARKS

In this chapter, the context of the study has been described and the research goals and questions were discussed. It is naturally important to understand the background of the study and the rationale behind it, which is why the significance of the study had to be described. The research design and approach was outlined. It was also important to identify the research site and the research participants. Data gathering techniques were addressed. In the next chapter the literature that supported the study is discussed. The views and the findings of other scholars on the topics related to my study are discussed.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discusses earlier findings relevant to the study of how Grade 10 Physical Sciences learners make sense of resultant vectors. The South African curriculum documents are examined as to how they address the concept of sense making in science. Then, literature on problems associated with the learning of resultant vectors is explored. Lastly, the theoretical framework informing this study is discussed followed by an overview of the chapter.

2.2 SOUTH AFRICAN CURRICULUM

Since the dawn of democracy in 1994, South African education has had three major revisions of curriculum. The earliest version which was born with the newly democratic South Africa was based on Outcomes Based Education (OBE) expressed through Curriculum 2005 (C2005). In C2005, learning was measured through the outcomes of learning. C2005 paved the way for the National Curriculum Statement (NCS) which was implemented in 2006. NCS was revised and was termed Revised National Curriculum Statement. This was implemented in 2010 which was later followed by a supporting document or policy called Curriculum Assessment and Policy Statement (CAPS) being introduced in 2012. It is to be noted that CAPS is not a curriculum, but a supporting document to RNCS. Table 4 below tabulates the differences between the earlier curricula versions.

Table 4: Differences between OBE and RNCS:

OBE	**RNCS**
• Deals with input and output (Olivier,1998) • Learners learn at their own pace (DOE, 1997:6). • Learner–centered (*ibid*.)	• Variety of learning strategies. • Culturally and aesthetically sensitive. • Participatory learning. • Learner-centered and activity-based. • Based on learning outcomes.

	• Cooperative learning (group work) (Du Plessis, 2013).

Seeing that OBE was modified and upgraded to RNCS, the focus of this study will mainly be on CAPS as a supporting document. It may be noted though, that OBE and NCS were modified in an endeavor to improve the standard of education. CAPS documents specify the following for Grades 10 to 12, in relation to Mechanics, vectors included:

- In Grade 10, the curriculum requires that the learners should know the concepts of vectors and scalars; motion in one dimension (reference frame, position, displacement and distance, average speed, average velocity, acceleration, instantaneous velocity, instantaneous speed, description of motion in words, diagrams, graphs and equations). They should also know about energy [gravitational potential energy, kinetic energy, mechanical energy and conservation of mechanical energy (in the absence of dissipative forces)].

- In Grade 11, the curriculum requires that the learners should have knowledge about vectors in two dimensions (resultant of perpendicular vectors, resolution of a vector into its parallel and perpendicular components), Newton's Laws and their application [Newton's first, second and third laws and Newton's law of universal gravitation, different kinds of forces: weight, normal force, frictional force, applied (push, pull), tension (strings or cables), force diagrams, free body diagrams and application of Newton's laws (equilibrium and non-equilibrium)].

- In Grade 12, the learners are expected to: describe momentum and impulse (momentum, Newton's second law expressed in terms of momentum, conservation of momentum and elastic and inelastic collisions and impulse), vertical projectile motion in one dimension (1D) (vertical projectile motion represented in words, diagrams, equations and graphs), work, energy and power (work, work-energy theorem, conservation of energy with non-conservative forces present and power) (CAPS, 2012).

For Grade 10 Term 3 learners are required to:

- define a resultant vector; and

- find a resultant vector graphically using the tail-to-head method as well as by calculation for a maximum of four force vectors in one dimension only.

Even though there is a clear link between what is expected of the Grade 10 learners and the expectations in Grade 12, the latter learners do not do well on the topic of vectors, as expressed in the 2010, 2011 and 2013 National Senior Certificate (NSC) (Department of Basic Education) examiners' reports. The examiners gave feedback of poor performance by Grade 12 candidates specifically on mechanics under which resultant vectors fall. They highlighted that learners are not performing well on the topic of vectors.

For example, the examiner's report, 2010, revealed that candidates could not write the equation of forces acting on an object, $W = f\Delta x Cos\theta$. The other challenge highlighted by the report is that the learners could not relate between the *fhorizontal* and *Cosθ*. This was exacerbated by the fact that learners confused the symbolic representation of the concepts (W= work; *f* =force; *Cos θ*= relationship between an angle and a vector). Yet, the interpretation of symbols in Physical Sciences enables the basic understanding of concepts by learners and force (*f*) is a topic taught in Grade 9 according to CAPS (DBE, 2012). Similarly, trigonometric ratios are introduced in Grade 10 on vectors acting at an angle to each other.

So, it could be argued that a solid foundation of resultant vectors for Grade 10 should be built on related content in Grade 9, as informed by curriculum expectations. This is known as the integration of learning across the grades. Integration refers to combining the knowledge from one grade to the next or the linking of the knowledge from one subject to the next (Welchman-Tischler, 1992). To this end, Wood, Bruner and Ross (1976) suggest that teachers should help learners to recall what they have learned in the previous grades so that they can easily make sense of the next grade's knowledge.

2.3 CHALLENGES ASSOCIATED WITH VECTOR CALCULATION IN SCIENCE

Vectors form part of Physics and Mechanics in different ways: as a transformation, force, velocity and acceleration. Generally, vectors are referred to as physical quantities that have both magnitude and direction and the resultant vector is a single vector which will have the same effect as the original vectors acting together (Brink & Jones, 1986). Additionally, vectors can be presented algebraically and graphically and in multidimensional form.

The literature is replete with studies reporting that learners usually regard Physics as conceptually difficult, abstract, uninteresting and as a discipline only suitable for exceptionally talented and gifted pupils (Barmby & Defty, 2006; Doug, 2010; Ancell, Guttersrud, Henriksen & Isnes, 2004). In their study conducted in England and Wales, Barmby and Defty (2006) found that more able pupils were doing science as separate subjects and that learners were grouped according to their ability to do science. As a result of this kind of perception, most learners find it really difficult to learn science. However, it may not be easy to come with the exact reasons why learners are not doing well in science. Doug (2010) explained that some learners fail Physics due to the negative perceptions they hold but it could also be argued that this perception is caused by lack of mathematical skills (Alberta Education, 2007 in Doug, 2010).

Prescott and Mitchelmore (2005) indicate that learners have difficulty with projectile motion. Secondary school learners (and even teachers) in Australia were also found to experience cognitive conflicts in grasping the underlying principle of horizontal and vertical motion simultaneously in projectile motion (*ibid.*). It is recognized that whereas learners tend to associate their problem with the difficult nature of physics, many teachers consider that insufficient mathematical competency of learners contributes greatly to their difficulties. Teachers see this as a major hindrance to learners' competency in Physical Sciences, in particular, the Physics section (Erinosh, 2003). In support, Freudenthal (1993, p. 72) argues that "among the sciences, mechanics is the closest to mathematics, in particular geometry". This relationship between mathematics and mechanics was earlier emphasized by Creighton (1985) who argued that, of all the fields to which one might wish to apply mathematics, mechanics has the strongest claim to prominence.

Other studies have also underlined the importance of competency in Mathematics for Physics (Funda, William, Robinson & Mark, 2008). A study conducted in Nigeria by Ogunleye (2009) also revealed that many learners perform algorithmic or mathematical manipulation by rote learning. Learners memorize formulae without having a basic understanding of specific concepts (*ibid.*). Ogunleye (2009) also found that learners were unable to construct meaning from problem statements. This challenge that the learners face in Mathematics has also affected their performance in Science. It can be argued that when there is no integration of concepts, learners find it difficult to make sense of new learning and that issue is discussed in section 2.4 below.

2.4 SENSE MAKING IN SCIENCE

Sense making is a term introduced by Weick (1995) denoting simply ‘the making of sense’ (Weick, 1995, p. 4). According to him, it refers to how we structure the unknown to be able to work on it, a view supported by Ancona (2007) and Waterman (1990). Ancona (2007) emphasised that sense making is more possible when people own the objective of the action. In the classroom, learners must know the objectives of every lesson presented to them. This enables learners to “comprehend, understand, explain, attribute, generalize, and predict” (Starbuck & Milliken, 1988, p. 51).

Sense making enables learners to have a better grasp of what is entailed in the content to be learned (Weick, 2001). According to Weick, learners will re-organize the existing knowledge in order to understand the new one. Sense making also involves motivating learners to move forward with the new knowledge. According to Weick, Sutcliffe and Obstfeld (2005), sense making further enables learners to work and adapt to the new learning environment. They emphasise that sense making forms the basis for the new learning to take place. It also reduces fear and anxiety about the new content to be learned. For an example, although the concept of resultant vectors might be new to learners, linking it with their prior everyday knowledge will facilitate their learning.

2.5 PRIOR (EVERYDAY) KNOWLEDGE

The promotion of experiential learning emphasizes that experience is the basis of most teaching and learning (Dewey, 1938). Experience naturally refers to the ‘past’, and it is the product of prior knowledge. So, we cannot talk of knowledge if someone is without experience. Dewey (1938) also emphasized that inquiry involves the continuous reflection on past (*á posteriori* knowledge). This means that the acquisition of knowledge is always measured against past experience. Learning is the process whereby a living creature gains knowledge through experience. For example, in a school situation, learners can learn vectors by means of interaction with the more knowledgeable other and also with the environment.

Learners are, however, more likely to construct an interpretation that concurs with what they already know, and be reluctant to accept the view point of the teacher (Roschelle, 1995). This means that learners’ prior knowledge must be valued in the classroom situation. Scott, Asoko and Driver (1991) have warned that the new knowledge must be built on relevant prior knowledge of the learner. In this way, learners will be able to adapt to conceptual change.

Unlike Dewey, Piaget focuses on the developmental stages which usually complement each other. These developmental stages are categorised as sensory-motor, pre-operational, concrete operational and the formal or the abstract operational (Piaget in Corsini, 1994). The present knowledge leads to the future learning or the future knowledge. Each step allows the learner to move from one stage to the next while the experience of one stage forms the foundation of the next. Piaget's theory (Inhelder & Piaget, 1958; Ginsburg & Opper, 1979) concerns the expansion of the schemata in relation to the realisation of the new knowledge. That is, Piaget's focus was mainly on cognition.

In contrast, Vygotsky believes in social learning. That is learning takes place through the interaction between the learners themselves and with the society to which they belong (Vygotsky, 1986). The experience or the knowledge learners have, is to be taken into the classroom situation. Some of the studies conducted by Vygotsky (1986) were mainly based on the role of prior knowledge in science learning. He argued that the partial knowledge of the child must be taken into consideration during the teaching and learning situations.

2.6 THEORETICAL FRAMEWORK

A theoretical framework provides a structure on which a research project is based (Merriam, 2002) and hence influences every aspect of the research, namely, the research problem, methodology, data analysis and interpretation. Hitchcock and Hughes (1995, p. 21) suggest that assumptions about the reality of enquiry and nature of things give rise to epistemological assumptions. It is therefore very important to consider which theory will make the findings authentic and valid. This study was informed by Piaget's cognitive constructivism and Vygotsky's social constructivism in conjunction with mediation of learning.

2.6.1 Constructivism

Constructivism is based on the view that learners construct their own knowledge, strongly influenced by their prior knowledge. In this way, learners construct their own individual sense of understanding (Tobin, Tippins & Gallard, 1996). Furthermore, constructivism means that the new knowledge cannot exist outside someone's existing knowledge (von Glasersfeld, 1988; Moll, 2002). In this regard, the new knowledge is linked to the existing knowledge. Essentially, constructivism implies that people construct their own understanding and knowledge of their environment through experiencing things and reflecting on those experiences.

Constructivist theory is an appropriate lens to understand this study since the teacher needs to enable learners to apply their everyday knowledge when learning about resultant vectors. Additionally, the teacher serves as a facilitator or mediator who helps the learners to achieve their individual understanding (Bauersfeld, 1995). Therefore this study focused on Piaget's cognitive constructivism and Vygotsky's social constructivism and mediation of learning.

2.6.2 Cognitive constructivism

Derry (1996) defined cognitive constructivism as a general metaphorical assumption about the nature of cognition that virtually all cognitive educational researchers accept, and emphasised that it should not be regarded as a unique theoretical framework, pedagogical approach, or epistemology. Atherton (2009) defined cognitive theory as being about the individual learner understanding the world around him. As much as the topic on resultant vectors is abstract, the learners will need their individual interpretation of its concepts. The learners' own rationale will thus be vital in the sense making of resultant vectors.

Cognitive constructivism is limited to the individual who is learning. Driver (1994) argues that while scientific and mathematical knowledge is socially constructed and science learning is acculturation, on the other side cognitive constructivists are more interested in the development of individual learning. Cobb and Yackel (1994) assert that it is not easy to separate social, socio-cultural and cognitive constructivism. They considered that the three concepts are mutually implicated in the learning process and cannot be separated.

2.6.3 Social constructivism

As introduced in Chapter One, this study was supported by the theory of social constructivism (Vygotsky, 1978) which caters for both the personal and social dimensions of learning, taking in account that knowledge is socially constructed within a community and learners are at the centre of learning. Furthermore, active involvement of learners during the learning contributes to a better understanding of scientific concepts, which in the context of this study are resultant vectors.

This active involvement is realized through teacher-learner interaction in interpreting the world (Lemke, 1990). For the processes to succeed however, learners need to enter into a discussion, that is, a 'shared enquiry' with one voice answering another. On this basis, "teachers need to teach learners how to engage in the discussions through which knowledge is constantly being constructed, deconstructed and reconstructed" (Wegerif, 2006, p. 60).

Social constructivism is characterized by learner-learner and teacher-learner interactions. In the process of interaction, language plays the key role (Lemke, 1990). Referring to mediation of learning, Lemke (1990) modeled that the teacher plays the role of the more knowledgeable other (MKO), giving direction to learners through talking and explaining. This learning theory provides a key on how to assist learners to make meaning of the environment around them (Hodson & Hodson, 1998). In the context of this study, learners must be able to use their surrounding environment in order to make sense of resultant vectors in Grade 10. Further, the learners must seek a connection between what they already know and the concepts and the new terminology involved.

The other feature of social constructivism is that the learners must bring their own knowledge into the classroom (Hanisi, 2006). Hanisi emphasized that prior everyday knowledge of the learners enhances their new learning. For instance, in the context of this study learners are engaged with the activities involving vectors on a daily basis. They pull or push their toys and they understand a "tug of war".

Figure 1: Showing a tug of war:

So, learners could be asked to give an example of any activity that involves vectors. In that way, knowledge might be constructed.

Keogh and Naylor (1996) noted that learners will only make meaning of the new situation based on their existing knowledge. The learners' daily activities will always involve vectors and resultant vectors. It can be argued however, that learners will not realise that what they are involved in involves vectors until such time as a more knowledgeable other (MKO) intervenes with their learning. That person can be a teacher or even a fellow learner. It is the duty of the teacher therefore, to help learners link what they learn in class to what they already know.

2.6.4 Mediation of learning

Learning is a process that needs the guidance of persons who have knowledge of the content to be learned. By mediation, I refer to the medium through which learning is being facilitated. One of the tools for understanding learning mediation is the zone of proximal development (ZPD) introduced by Vygotsky (1978). As outlined earlier, the ZPD refers to the learning that takes place with the MKO. The ZPD defines the gap between what the child can do on its own and what the child can do but with the help of others (Ellis & Worthington, 1994). It is thus the duty of the teacher to establish the level of the learners' understanding. Bransford, Brown and Cocking (2000) discuss the guided learning experience which informs the concepts of ZPD and scaffolding whereby for effective learning to take place, teachers must guide the learners during the learning process so that there can be sense making (See Section 2.4).

As discussed above, learners reach the next level of learning through the assistance of the teacher and it is the duty of the teacher to assist learners during the science lesson. However, the teacher is not the only knowledgeable other, indeed the normal groupings of learners also contribute to effective learning (Rosenbaum, 1988). Normal grouping refers to learners being heterogeneously placed according to their different abilities. This will help them make sense of their learning of the content.

Bruner (1975) explains scaffolding as the process whereby a learner is guided to achieve higher levels of learning. The teachers must lead the process of learning new concepts. Wood, Bruner and Ross (1976) have defined scaffolding as the support given to the learner by an adult person, a MKO.

2.7 CONCLUDING REMARKS

In this Chapter, I discussed the literature in relation to sense making of resultant vectors, starting with a review of curriculum developments in South African education and the place of vectors within it, in successive school grades. The literature on prior everyday knowledge was discussed, focusing on how learners use their everyday experiences in learning new concepts. The constructivist theoretical framework informing the study was also discussed. In the next chapter, the research methodology is presented.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter focuses on the methodology used to collect data about the topic of research. The sections of this chapter are in the following sequence. Section 3.2 outlines the research goal and the research questions. The research design is dealt with in Section 3.3 involving the research paradigm and research approach. The research site and the research participants are then discussed. Data gathering techniques took the form of a diagnostic test, lesson observation and document analysis. These techniques are discussed in Section 3.3.3. The chapter concludes with a discussion of research trustworthiness, validity, ethical considerations and the limitations of my study.

3.2 RESEARCH GOAL AND RESEARCH QUESTIONS

In accordance with the aim of this study, I sought to answer the following main question:

- How do Grade 10 Physical Sciences learners make sense of resultant vectors?

The following sub–questions were used to help answer the main question:

- What prior knowledge do the Grade 10 Physical Sciences learners have on the topic of resultant vectors?

To answer this sub-question, I analysed the learners' responses to a diagnostic test. I also noted learners' responses during lesson discussions, which revealed their knowledge of resultant vectors.

- What kind of learning mediation is required to help learners make sense of the topic of resultant vectors?

The lessons were observed, videotaped and transcribed before being analysed.

- What are the challenges encountered by the Grade 10 learners in calculating resultant vectors?

This question was answered through a diagnostic test, worksheets and a summative test.

3.3 RESEARCH DESIGN

The methodological framework that guided the research process is presented with a discussion of the reasons for selecting an interpretive paradigm and qualitative case study approach to address the research goals and questions. My own role as a researcher during the research process is also reflected on.

3.3.1 Research paradigm and research approach

My study was underpinned by an interpretive paradigm. The interpretive paradigm is concerned more with the individual or a specific group of people, "getting inside the person and to understand from within" (Cohen, Manion & Morrison, 2011, p. 17). According to Guba (1990), a paradigm is a pool that holds the researcher's epistemology, ontological and methodological properties guiding the action. The term is also explained by Denzin and Lincoln (2008) as carrying the ethics, epistemology, ontology and methodology for an action. In the context of this study, the interpretive paradigm helped provide some insight into how the Grade 10 Physical Sciences learners make sense of the topic of resultant vectors.

Extending from the interpretive paradigm, a qualitative case study was employed. A case study is defined as the study of a particular event or action (Stake, 1995). A case study is usually a response to an action or an event (Adelman, Kemmis & Jenkins, 1980). This kind of study also involves mixed methods. It was partially quantitative in the sense that marks and percentages were used. However the study was more qualitative with a focus on observations and the "how" part of sense making.

Tashakkori and Creswell (2007, p. 4) define mixed methods as "research in which the investigator collects and analyses data, integrates the findings, and draws inferences using both qualitative and quantitative approaches or methods in a single study or program of inquiry". The mixed methodology has potential to address a combination of multiple paradigms (e.g. pragmatism, transformative, critical realism and dialecticisms) in research as an endeavor to address matters of particular interest, such as knowledge, epistemic and social values and causality (Christ, 2011).

3.3.2 Research site and participants

The research participants in this study were a teacher and her class of about 35 learners in a Grade 10 Physical Sciences class at Komadihare Secondary School (pseudonym) where I also teach. Purposive sampling was used to choose the research participants amongst the learners after administering a diagnostic test to the entire class. The diagnostic test was one of the techniques of data gathering used for the purpose of planning for intervention where possible.

The lessons were observed during the teaching and learning of resultant vectors by Grade 10 learners. The lessons were video-recorded as part of data gathering. Then a focus group consisting of 6 members was purposefully chosen to achieve a spread in ability so as to elicit informative data. The data collected helped in identifying shared themes within the sample.

3.3.3 Data gathering techniques

Cohen et al. (2011) define data gathering as techniques that are to be used in the collection of information for one's research. They emphasise that numerous techniques may be engaged as they complement each other in some instances and validate the data. Mixed methodologies of data gathering were used in this research as already discussed in Section 3.3.1. This approach was relevant for my study as I would be intervening in a situation where Grade 10 learners were not doing well with regards to the learning of vectors. This kind of research would force me to consider interchangeably both qualitative and quantitative approaches.

In support of Christ (2011), Yin (2009) identifies six sources of data namely documents, interviews, archival records, direct observation, participant observation and physical artifacts. Unlike in other qualitative approaches, case study researchers can gather and integrate quantitative survey data, which facilitates reaching a deeper understanding of the topic being studied. However, in this study I used a diagnostic test, lesson observation and document analysis.

3.3.3.1 Diagnostic test

Learners' understanding of scientific concepts must be of considerable interest to teachers. However, learners' effective understanding of scientific concepts is dependent on what they already know. In simpler terms, the prior knowledge of learners determines the extent to which the new knowledge is to be learned. Prior knowledge was discussed in the literature review but it may be noted here that prior knowledge is what is measured in a diagnostic test. In particular, a diagnostic test may be used to diagnose learners' misconceptions.

Learners' conceptions which differ from those generally recognised by the curriculum have been called 'misconceptions' (Helm, 1980), 'preconceptions' (Novak, 1977), 'alternative frameworks' (Driver, 1981) or 'children's science' (Gilbert, 1982). To determine children's misconceptions, Piaget used interviews. Osborne and Gilbert (1980) and Watts (1981) define a variety of interview procedures. The most common procedure used by researchers is the interview. Mitchell and Gunstone (1984) use an interview format which is a mixture of different procedures. As stated before, a diagnostic test can be used to ascertain any misconceptions that the learner might have. This kind of test is sometimes called placement testing whereby a learner is placed at the right level of competency (Gronlund & Linn, 1990). Cohen et al. (2000), supporting Gronlund and Linn (1990), cited that diagnostic tests help the researcher to gather a lot of data about their topic of research.

For this study, a diagnostic test was administered to Grade 10 learners who were doing Physical Sciences. This was a short test aimed at finding out what knowledge the learners had relating to vectors. The test content was mostly drawn from the Grade 9 work associated with vectors, for example, force. In Grade 9, learners are expected to learn and understand forces including contact and non-contact forces, field forces, magnetic forces and electrostatic forces (South African Department of Basic Education [DBE], 2011). It is also to be understood that force is an example of a vector since it has both magnitude and direction.

3.3.3.2 Observations and participant observations

The learning observation was an important part of data gathering. Observing involves a lot of activities: note taking, behavior, settings and artifacts for every event (Marshall & Rossman, 1995; Simpson & Tuson, 2003, p. 2). The actual classroom observation was supplemented by analysis of video records of the lessons. Video recording is convenient for analyzing the data because it is possible to watch the lessons as many times as required. It is also useful in the validation of data, by reviewing and re-playing during transcription.

On the other hand, it is important to consider the disadvantages of video recording, in particular the distraction that might be caused by the presence of recording equipment during the lesson. Some learners may be excited or shy away from being on camera. That on its own will affect their learning. For example, in my class one boy covered his face with a book. He could not focus on what was being taught because his concern was to not to appear on the camera. At the same time, I am an HOD in my school, so my presence in the class could also pose a different problem, creating a tense atmosphere in which learners might tend to behave in an unusual way.

3.3.3.3 Interviews

An interview is defined as "a dialogue between the researcher and the research participant on a subject based on the study" (De Marrais, 2004, p. 55). In the study I carried out semi-structured interviews with a focus group and stimulated recall interviews (SRI). Miller, Blessing and Schwartz (2006) echo the value of the use of interviews and argue that interviews provide a deeper understanding of specific aspects under investigation. Although interviews have their drawbacks, such as being dominated by a few in the case of face-to-face interviews, they can be a useful way to get in-depth data (De Marrais, 2004). There are different forms of interviews and I discuss these below.

3.3.3.4 Semi-structured interviews

The use of semi-structured interviews was used in this study to uncover how learners made sense of resultant vectors during lessons. Semi-structured interviews according to De Marrais (2004) are essential when it is difficult to perceive attitudes such as behaviour, motives, feelings, intentions or how people interpret the world around them. Most qualitative studies employ semi-structured interviews (Merriam, 2009). In this study, semi-structured interviews afforded me an opportunity to probe the participants' responses and to ask for clarifications through follow-up questions.

Probing questions were used to ensure that the questions were answered as fully as possible. The interview schedule (Appendix I) had six open-ended questions which directed the interviewing process on the ten learners who constituted the focus group. The interviews were face-to-face and were videotaped by another teacher at the school who is a Master's student. A pilot test of the interview questions was conducted with some learners. This assisted me to restructure the questions after they were discovered to be colloquial. As a result of the pilot, I had to increase the number of questions to ensure that all the research aspects were covered during the interviews.

3.3.3.5 Stimulated recall interviews

A stimulated recall interview (STI) is described as "an introspection procedure in which videotaped passages of behaviour are replayed to individuals to stimulate recall of their concurrent cognitive activity" (Lyle, 2003, p. 861). The rationale for the STI was to gain an in-depth understanding of how learners make sense of resultant vectors. This data gathering technique was quite useful in the research process as I managed to fill in gaps existing in the data.

3.3.3.6 Document analysis

Maree (2011, p. 82) defines document analysis as the “analysis on all types of written communications that may shed light on the phenomenon that you are investigating”. This supports the position that any document related to the investigation under study can be used. The documents for my study included mostly the examiners’ reports for Physical Sciences and learner responses regarding the impact of sense making on the topic of resultant vectors. The learners’ responses to the worksheets and summative test were also analysed. Also included in the documents analysed were textbooks and CAPS documents for Grades 10, 11 and 12.

3.4 DATA ANALYSIS

Qualitative data analysis aims at making sense of the information gathered. This is done by organizing and structuring information into themes to be used (Cohen et al., 2011). This involves the systematic arrangement of the data to suit the study. Cohen et al. (2011) emphasize that not all data are relevant for any study or research. Therefore data collection must be purposeful.

Data from the diagnostic test were analyzed to find how the learners answered the questions on resultant vectors and in particular, whether their answers emanated from a deeper understanding. The observed lessons were video recorded and analyzed and compared with literature and other findings on my research topic. The examiners reports, CAPS documents and textbooks were consulted for categorizing important and relevant ideas that answered the research questions. The feedback of the learners from a summative test also formed part of data analysis.

3.5 VALIDITY OF MY STUDY

The main provision for validity in this research was the triangulation in gathering different kinds of data. Triangulation reduces the chances of an inaccuracy (Maxwell, 2005). In this way, validity was established so that information gathered could be considered as true, dependable and without bias (Merriam, 2002; Denzin & Lincoln, 2008; Cohen et al., 2011). Analysis of the diagnostic test and playing back the videos with the teacher participating in my study also helped in the validation of data gathering techniques.

To support and strengthen the data collection, the participants in the lesson observations were given a chance to reflect on the effectiveness of learning the research topic using stimulated recall interviews.

3.6 ETHICAL ISSUES

Cohen et al. (2011) consider that the honoring of ethics in research is of paramount importance to ensure the reliability and validity of a study and also emphasize the significance of seeking the permission and informed consent of participants. That can be extended to informing parents about the activities their children would be engaged in. As I was not teaching Physical Sciences in Grade 10 at the time of this study, I needed to ask for informed consent from the intended teacher to participate in my study.

The contents and the purpose of the study needed to be presented to the teacher and to the Principal of Komadihare Secondary. Permission needed to be granted before taking photos and video recording of the lessons to protect the integrity of the participants in the research process (Frankfort-Nachmias, 1992). The researcher needed to be careful to not waste the time of the people who participated in the study (Cohen et al., 2011). In other words, the research must benefit both the participant and the researcher. As Head of Department at Komadihare secondary, I had to take into consideration whether power relations might influence my research. I was then bound to assure the teacher that the information to be gathered was not going to be used for departmental purposes.

3.7 LIMITATIONS OF MY STUDY

Given the nature of this research as a case study involving one grade and one school, the results could not be generalised (Bogdan & Biklen, 1992). Focusing on a few learners out of a class of 35, cannot guarantee that learners not forming part of the sample would have behaved as observed. This agrees with Bertram and Christiansen (2014) when they note that any observation is selective. The researcher cannot observe most of the actions and activities at the same time.

As much as video recording is good for data gathering, it has its own disadvantages. It tended to make learners distracted and excited, which might have disturbed the lesson itself. Consequently, the results might not have been as authentic as expected. However, it will lay the foundation for future research on the topic.

3.8 CONCLUDING REMARKS

In this chapter, the methodological orientation was discussed, namely, a case study underpinned by the interpretive paradigm using mixed methods. Hence, the study took the form of both qualitative and quantitative approaches. The research design and research participants were detailed as well as the data gathering techniques used. The discussions included the data analysis, validity, the ethical considerations as well as the limitations of my study. The next chapter presents and analyses the data.

CHAPTER FOUR

DATA PRESENTATION AND ANALYSIS

4.1 INTRODUCTION

In this chapter, I present the data gathered from the various techniques described in the previous chapter, namely, a diagnostic test, learning observation, a summative test, semi-structured interviews reinforced with stimulated recall interviews and document analysis.

The chapter begins by profiling the learners I worked with in terms of their age, gender and whether they were repeating the grade. The process of administering the diagnostic test is described, as well as how the learners performed. The processes involved in the learning observations are outlined and the findings described. Learning observation allowed the identification of salient features of learners' responses to the lessons on vectors. The learners were also given a summative test, the findings from which are presented. To consolidate these findings, the learners were interviewed concerning the lessons observed. The transcriptions of these interviews are presented. In conclusion, the summary of the whole chapter is briefly discussed.

4.2 LEARNERS' PROFILES

I considered it imperative to give the profile of the learner participants because this could affect the study in one way or another. Their age ranged between 15 and 20 years. Within this range, seven learners were aged 15, 11 were aged 16, eight were aged 17, six were aged 18 while three were aged 20. In spite of the Department of Education in South Africa requiring learners in Grade 10 to be of age 16 and less, the situation was not the same in this school. This is not an alarming situation seeing that some learners in rural areas delay their schooling start. Some had failed the lower grades. In this class of 30 learners with 19 girls and 11 boys, 12 were repeating Grade 10.

4.3 DIAGNOSTIC TEST

The diagnostic test was administered to the whole class, the purpose of which was intended to get an understanding of the learners' level of knowledge in relation to resultant vectors. I had also hoped to understand the learners' prior knowledge. Therefore, and as mentioned in the previous chapter, the test content was based on the work of Grade 9 mixed with a little of what to expect in Grade 10 (see Appendix C). Questions were also drawn from the CAPS documents of both Grade 9 and Grade 10 and from textbooks aligned to CAPS. It may be noted that CAPS documents are related and integrated across the grades. CAPS documents of Grade 9 Natural Sciences, link with that of Grade 10. In other words the 'forces' taught in Grade 9, will be expanded further in Grade 10. This is why both grades were considered when preparing the diagnostic test.

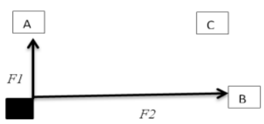
4.3.1 The structure of the diagnostic test

Questions 1 and 2 were based on the Grade 9 topics with the main focus on forces. The learners had to define force and display some knowledge about the characteristics of forces. The questions were only on forces because in Grade 9, no mention of vectors is made (CAPS work schedule) (see Appendix D).

Question 3 was more orientated towards the work of Grade 10. It was also intended to assess learners' prior everyday knowledge. The purpose was to check if learners were able to apply the knowledge from Grade 9 on higher order questions. It was framed as shown below:

QUESTION 3:

Consider the diagram below:



3.1. Identify the position of the object after the forces F1 and F2 have acted on it. Choose from the positions given, A, B and C.

/2/

3.2. Give reasons for your answer above. */2/*

3.3. Describe F1 and F2 in terms of their orientation (Horizontal OR Vertical)

/2/

3.4. Give an estimation of the angle between F1 and F2.

/2/

The table below shows the summary analysis of the diagnostic test.

Table 5: Diagnostic test results:

Questions	**Question 1**					**Question 2**			**Question 3**			
Sub-questions No.	1	2	3	4	5	1	2	3	1	2	3	4
Correct	80%	80%	30%	50%	60%	80%	80%	10%	30%	30%	40%	60%
Incorrect	20%	20%	70%	50%	40%	20%	20%	90%	70%	30%	60%	40%

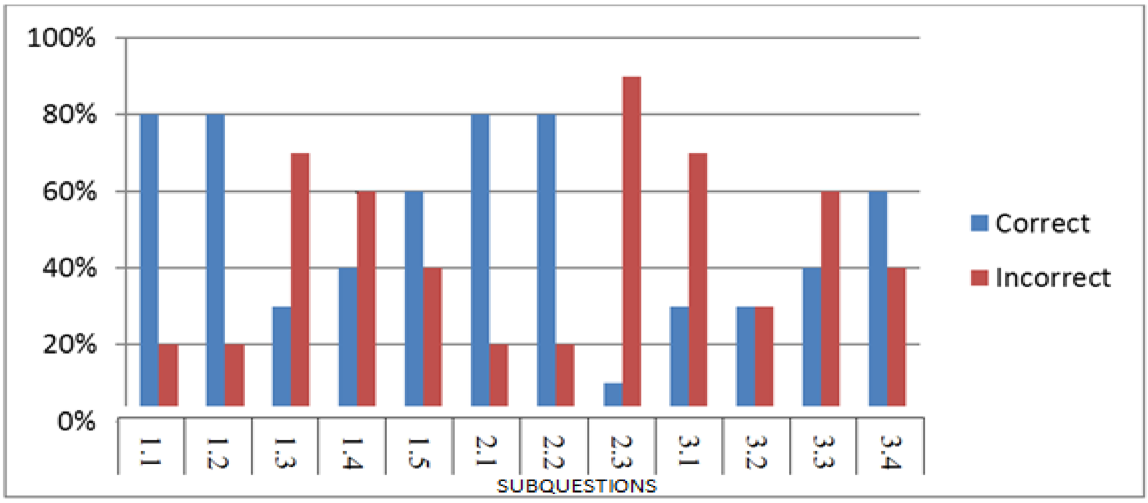
Out of the 30 learners who wrote the diagnostic test, 18 (60%) passed question 1, 17 (57%) passed question 2 and only 12 learners which is about 40% managed to score high in question 3.

Table 6: Analysis of results from the diagnostic test:

Total pass rate	55,8%
Total fail rate	44,2%

The results in Table 6 above are presented graphically on the figure 2 below. It gives the spread of marks between the correct and the incorrect responses of the learners.

Figure 2: **Showing the percentage of correct and incorrect responses from the diagnostic test:**



As Question 1.1 asked about the learners' prior knowledge, about 80% of them knew the definition of force. L2 defined force as: *The ability to do something, to force up or down* (Appendix E, L2 R – DSQ 1.1). They were also able to explain whether forces can be added or subtracted in Question 1.2. However, they could not understand when to add and when to subtract forces. L3 gave the answer as such: *When an object needs more force we add force* (Appendix E L3 R – DSQ 1.3). L2's response to Question 1.4 was: *If we subtract forces we want them to not be strong or to take something easily* (Appendix E, L2R – DSQ 1.4). The responses from questions 1.3 and 1.4 suggested that although these learners knew about forces, they needed to be taught how to add or subtract them. Moreover, addition and subtraction of vectors is in the Grade 10 syllabus, while the diagnostic test was based more on Grade 9 work. Even though many learners could not answer questions 1.3 and 1.4 well, about 18 (60%) of them were able to differentiate between vector quantities and scalar quantities. This 60% of learners might have been repeaters of Grade 10 (see 4.2 above).

Question 2 was more about the effect of combined forces which involved their addition and subtraction. It is not surprising that about 90% of the learners got sub-question 2.3 wrong. Sub-question 2.3 asked about the effect of equal forces acting in the opposite direction and was similar to question 2.2.

Question 3 was not answered well seeing that only 40% passed. This question tested Grade 10 work on the resultant vector.

4.3.2 Reflections on the diagnostic test

The diagnostic test was mainly meant to answer sub-questions 1 and 2 of the study and it was intended to establish the learners' understanding of resultant vectors. Hence, the diagnostic test provided some information on how to introduce the lessons on resultant vectors. Similarly, sub-question 3 was also responded to since the learners' responses showed challenges they have on forces and vectors.

However, the standard of the diagnostic test was moderately acceptable considering that only about 44% of the learners failed the test. So, one cannot ignore the influence that outliers have on the data. For instance, it might have been more useful if only those learners in Grade 10 for the first time were subjected to the test. This might well have presented a different picture. Although it might be ethically problematic to subject some to a test and others not, for authenticity and validity of the data, that would be the route to follow in future. The full transcription of the learners' responses from the diagnostic test can be found in Appendix E.

4.4 LESSON OBSERVATION

Lesson observation offered me an opportunity to gather 'live' data occurring in a social situation, which in this case was a classroom (see Section 3.3.3 above). That is, this gave me more opportunities to observe how learning took place in real time as the teacher was teaching the whole class of 30 learners. It may be noted though that even though the whole class was being taught, the focus of the observation was on the sample participants (see Picture 1 below).

Picture 1: Learners' interactions during their class

Four lessons were observed each being one hour long. Although the plan was to observe five lessons, the first lesson was missed because the teacher could not inform the researcher when she was ready to start the topic on vectors.

4.4.1 Lesson observation one

The lesson began with the baseline assessment of what had been taught the previous day. The learners were asked questions by the teacher (T1). Some of the questions and responses were as follows. T1 asked the class "*What is the difference between the scalar and the vector quantity? Respond by show of hands".*

L1 responded that "v*ectors are having direction".* In response T1 asked "*By direction only?*" The teacher asked the question in a way to show them that the answer was incomplete. The class then answered in a chorus "*and magnitude*".

Thereafter, the teacher introduced the lesson by asking the learners to pull one another in a tug of war scenario. Due to weather conditions that day, this was done in the classroom. She started with two learners pulling one another in opposite directions. She then reinforced one learner with one more so that the competition was two against one. The two were easily out-pulling the single one. She then reinforced the one with another so that it was two against two. Now the balance was partially reached. One pair was reinforced by one more so that it was now three against two. The three overcame the two. L1 asked, "*E etsetsa'ng ntho ee miss*?" [Translated: Why are we doing this miss?]. The learners were now trying to construct meaning out of what was being done. The teacher replied to the whole class, in the form of a question, "*What do you think is the reason?*" L3 replied, lifting his voice up above the rest of the class, "*We want to see which group is stronger*".

The teacher started with the base line oral activity. The activity was based on what was taught the previous day. This assessment took almost 48 minutes (80%) of the lesson. The whole lesson was just a 'question and answer'. This was reflected by their chorus responses to some of the questions. After that lengthy baseline assessment, the teacher was ready to start the lesson of the day.

T1 began: "*Now I want us to focus on the vector quantities, the ones that have both magnitude and direction".* This was where the interest of my study really lay. She continued: "*We are* *going to focus on the addition of vectors".* This was now the time for teaching the new concepts. The learners were now listening attentively (see the picture below).

Picture 2: Learners' reaction to teaching

The learning process took place in different ways: through listening which is a skill for learning and through meditation. This is how new ideas are constructed and formed.

The teacher explained the importance of direction when vectors are acting together as follows: *"If the vectors are acting in the opposite direction, you choose which one is to be positive or negative".* This statement prompted some questions from the learners. L7 asked, "*Ha ke ntse ke bala mona bukeng ke utlwa ho thwe tse bang positive ke tse yang hodimo, mara wena o re motho o ipehela sign. Ho tla ha jwang*?" [Translated: When I read here in my book, it says that those going up are positive but you say we can choose which direction is to be positive or negative? How come?]

Picture 3: Learner seeking clarity

The picture above shows L7 arguing with T1 about the direction of a vector. I consider healthy and positive debates in a learning situation to be good. This learner sought to understand the issue of choosing the direction yourself. Arguments and discussions lead to sense making of the new information. T1 replied that*, "Any vector can be positive, it depends on you which one you choose to be in a positive direction".*

4.4.2 Lesson observation two

Lesson observation two was a period of 60 minutes. The learners were sitting in their normal manner. However, I requested that the focus group sit next to each other. In doing so, I was aligning myself with Bertram and Christiansen (2014) when they define purposive sampling as when the researcher makes a specific choice about which people (subject) will best represent the larger population. With this intention, I was able to narrow down my observation to a specific group.

On this day the teacher was teaching the learners how to calculate resultant vectors. The learners were given an exercise on calculating the sum of vectors acting in the same direction on a straight line and those that act in opposite directions. During this lesson observation, I realized that the learners were finding it a challenge to convert units from one to another. The exercise was given in Newton's and the learners were expected to represent these Newton's on a scale of millimeters. The educator spent most of the lesson explaining and scaffolding the learners on the conversions.

The scaffolding by the teacher allowed for a classroom discourse where learners got an opportunity to ask and to explain to each other. The bone of contention in all these discussions was the way of using a given scale in order to represent the Newtons as millimetres. L1 asked, "*Ke e fetola jwang hore e be dinewtons ho tloha ruleng? Ha ke re ruleng mona ke di millimetres?"* [Translated: Miss how do I change to Newtons using the ruler? Doesn't the ruler have millimetres?] The teacher replied *"Ha 1 N e lekana le 2mm, 5N yona e tla lekana le e eng?*"[Translated: if 1N is equal to 2mm, 5N will be equal to what?]. So in answering questions the teacher asked another one. This encouraged learners to think and reason on what they were learning. L2 answered,"*E tla lekana le 10mm*." [Translated: It will be 10mm]. T1 agreed that that is how you convert them. At that stage, other learners were getting the correct answers. That prompted them to call for attention from the teacher by raising their hands as in Picture 3 below. The teacher emphasised that learners must always describe the direction even if it is in words, for example, downwards or upwards.

Picture 4: The teacher mediating learning

At this stage the focus seemed to have moved away from calculating the resultant vector to converting millimeters to Newtons and vice versa.

L5 then asked the following question, "*Hobaneng resultant e tlamehile hoba le direction? E ne e le siyo ho di example tsa di vectors.*" [Translated: Why is the resultant supposed to have a direction? Resultant was not there in the examples of vectors]. T1 replied that, "*The resultant force is a vector because it always has direction. A resultant vector is a straight line starting from one point to the other*". This learner recalled that resultant was never mentioned under examples of vector quantities. She could not understand why the teacher was stressing the issue of direction when calculating a resultant vector. The learners had understood that everything that has direction and magnitude is a vector.

The lesson for day two had been totally diverted to the conversion of units. The conversion of units are taught in Grade 7 (CAPS for Mathematics, term 2, see Appendix F). The teacher in Grade 10 had to teach this Grade 7 work of converting units. This was valuable because it laid the foundation for the new knowledge to be acquired.

4.4.3 Lesson observation three

This was day three of the observation and again its duration was about 60 minutes. The sitting arrangement of the learners was as before with the focus group again sitting next to each other in pairs. In the previous day, the learners only did the addition and subtraction of vectors acting on a straight line. In other words, they were calculating the resultant vector of vectors acting linearly. The teacher started as usual with a baseline assessment: "*Who can describe the nature of the resultant vector of vectors acting in the same direction? Is it big or small*?" L1 answered by saying, "*It is… small…. it is big".* By this time L1 was hesitant about the answer and the rest of the class' hands were up. Their response was an indication that the previous day's lesson was effective.

For instance, T1 explained the use of a scale, while other learners were acquainting themselves with linear vectors and their resultant. T1 continued with her assessment. "*What happens if the vectors are acting in the opposite direction?"* The whole class responded in a chorus, "*It is small… it is zero… it is negative*". Three different answers were heard from that chorus. This was interesting because the teacher followed up with more questions. "*When is it zero*?" L2 replied: "*When vectors are equal but in the opposite direction".* The teacher continued, *"When is it negative?"* L3 replied, "*When they are…small*", while L4 said, "*When they are in the* *opposite direction".* L5 contributed by saying, "*When the big is subtracted from the small*". The teacher nodded and said, "*Very good. Mathematically, you subtract and take the sign of the big number*".

She continued. "*Today we are going to look into vectors acting at an angle. We shall consider the other methods of calculating the resultant vector. These methods are polygon, tail-to-head and parallelograms".* The teacher then illustrated and explained the polygon method. This was a time of tranquility and concentration in the classroom. This part was more about Mathematics and the chalkboard was full of triangles and polygons (quadrilaterals and other figures of the polygon family). It is in this section that integration across the subjects was revealed. The teacher had to make learners think and reason mathematically. L6 asked the teacher to explain further as he said, "I *do not understand this parallelogram method well? How do I construct a parallelogram?"*

Picture 5: Mathematical calculations of resultant vectors

4.4.4 Lesson observation four

In the previous lesson, the teacher had taught about vectors acting at right angles to each other (see the picture in lesson observation three). On this day the teacher started with the usual baseline assessment. She asked, "*What is meant by perpendicular vectors?"* The learners started to mumble the answer. The teacher asked if they could answer by putting their hands up. L1 replied first, "*Perpendicular means…*90^0". T1 asked for another meaning. L2 said, "*Perpendicular means right angle*". T1 confirmed that they were both correct. She asked again: "*How are perpendicular vectors then*?" L1 replied, "*They are acting at right angles".*

The baseline assessment took almost 30 minutes of the lesson as usual. The learners were doing some exercises on the board. The focus was on vectors acting perpendicular to each other. In particular, they were calculating the resultant vector using Pythagoras theorem. The teacher had to do some more explaining on how to measure the bearing of a resultant. T1 stated that "*the bearing of a resultant is referring to the direction with an included angle".* Demonstrations were used with the aid of a protractor ruler.

After that baseline assessment, the teacher started to introduce the lesson of the day. "*Today we are going to look at the magnitude of the resultant vector and the angle it makes with the other vector".* The teacher as usual asked questions: "*Which method are we going to use to calculate the resultant of vectors acting at an angle of* 30^0 *to each other?"* L1 replied: "*We are going to use Pythagoras theorem*". T1: "*Pythagoras theorem…? What did Mr. Motsilili say about the use of Pythagoras theorem*?" The teacher was trying to get them to remember some of the things taught in the previous lessons. L2 replied: "*We use Pythagoras theorem only when there is* 90^0 *between the forces".* T1 said that that was correct. She continued: "*Answer my previous question. What about the resultant of the forces acting at an angle of* 30^0". L3 said, "*Maybe we can find them by measurements… by measuring".* T1 explained further: *"Apart from Pythagoras theorem, we can also use the other methods. Mathematical methods like Trigonometry may be used. When one vector and an angle are given or known, we use the trigonometric ratios*".

Picture 5 below shows the shift from Pythagoras theorem to application of trigonometric ratios when calculating the resultant force. T1 continued: "*Now we shall talk of the horizontal force = x, the vertical force = y and hypotenuse force/ resultant force = r. Trigonometric ratios can help us to find the angle between forces by calculations".*

Picture 6: Trigonometry is used to calculate the component vectors

L2 asked the following question: "*In Mathematics we say,* $\tan\theta = \frac{opposite}{adjacent}$ *what we call that in Science?"* The learner seemed to associate the concept of *tan* with Mathematics. T1 explained: "*It is the same but here we talk of vertical force instead of opposite, horizontal force instead of adjacent and tension force or resultant force instead of hypotenuse".* The teacher continued with the explanation. She was now linking mathematical expressions with scientific concepts. T1: "*We can also use the ratios of* $\sin\theta = \frac{opposite}{hypotenuse}$ *and* $\cos\theta = \frac{adjacent}{hypotenuse}$ *depending on what is given*". This was not an easy section for the learners to understand. The teacher was now giving a series of examples on the board and letting the learners complete exercises from the text book. It was also clear that L2 who asked the question above was a repeater since many learners could not understand calculations with the use of trigonometric ratios. Some learners confirmed that they had not been taught these in Mathematics. T1 concluded by saying*: "Now let us give one another home work for the weekend and on Monday we are going to write a test which is going to be set by Mr. Motsilili. Are you ready for the test*?" All learners replied that they were!

4.4.5 Reflections on the lesson observations

Lesson observation one: The lesson did not go according to my expectations as the teacher did not notify me when she was going to introduce the topic. This led to a situation where, what was supposed to be lesson 2 became lesson 1. However, the teacher spent almost an hour revising what was taught the previous day in which she mainly used a 'question and answer' method.

Lesson observation two: The teacher had introduced the resultant vector the previous day. This is where the teacher had to adapt her lesson as she first had to teach an aspect of Mathematics (polygons and quadrilaterals). She was preparing the learners for the calculations on resultant vectors. It was clear that the learners lacked the knowledge from other subjects such as Mathematics. This showed the importance of integration of subjects and topics across the grades.

Lesson observation three: Since the learners were taught the resultant of linear vectors the previous day, this day the lesson was about the polygon method of calculating the resultant vector. The interaction between the learners and the teacher was vibrant. Learners were asking the teacher many questions which was a sign of sense making.

Generally, the lesson observations went well although it would have been useful if there had been at least two cameras. One camera was ineffective because it imaged one particular object at a time. While one group of learners was being photographed, other important actions and activities were being missed. Another problem was that I was simultaneously an observer and the cameraman. This prevented me from taking some notes during the process. If the study could be repeated, I would organise someone else to take the videos so that I could concentrate on taking field notes.

At the end of these lessons, learners wrote a summative test to check their understanding of resultant vectors and I discuss this in detail below.

4.5 SUMMATIVE TEST

On day five a summative test was written, based on all that had been taught during the observation period. The test was set out of 50 marks and was intended to serve two purposes. It was going to serve both as School Based Assessment (SBA) for the teacher (T1) and for the purpose of this study. It was aimed at assessing the learners' understanding of vectors and resultant vectors. The assumption was that if the learners passed the test that would indicate that sense making had taken place during the lessons.

The test comprised five questions following the Bloom's taxonomy levels of assessment (see Appendix G). Question 1 was a recall question using multiple choices. The learners were asked to choose the correct answer amongst the five distractors provided. My expectations about this question were that it would engage the learners' minds and they would do well. Unfortunately however their performance was not good.

In Question 2 the learners were asked to give definitions of scientific terminologies, for 10 marks, as shown below:

Define the following scientific terms:
2.1. Resultant vector
2.2. Vector quantity
2.3. Displacement
2.4. Scalar quantity
2.5. Energy

The learners could not define some of the concepts and scientific terms. The highest mark was 4 out of 10. Below is the extract of some responses to Question 2 from the summative test:

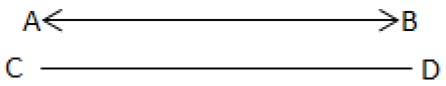
Table 7: Some responses from the learners for summative test Question 2.1

Statement / Response	Responses
Resultant vector is a resultant with both magnitude and direction	L1R
Resultant is a speed	L2R
Resultant vector is a vector that result both two vectors of tail to head	L3R 1
Resultant vector – it is that you get a point	L4R
Resultant vectors are physical quantities that have both sides	L5R
Resultant vector – physical quantity	L6R
Resultant vector -	L7R
Resultant vector – it is the outcome of a vector	L8R
Resultant vector is a quantity of vector tail to head	L9R
Resultant vector – the answer comes from the calculations	L10R

Some learners defined vector quantity as follows: L3: *Vector quantity is a vector that calculates the total amount of the quantity*. Some responses from learners showed a slight misconception. For an example they defined a vector quantity *as the physical equation that has magnitude and direction*. Even when learners could classify the given example of vector quantities and scalar quantities, they could not define them. However, not all the learners got the definition of vector quantities wrong. Some got the right answer. L8 wrote: *It is the physical quantity that has magnitude and direction.* More learner responses to Question 2 are discussed in Appendix G.

Question 3 was of moderately difficulty but still the learners did not do well, as reflected in the extract below:

3.1.



Describe the difference between the two lines AB and CD above in terms of vectors and scalars. */2/*

3.2. When do we say the vectors are equal? */2/*

3.3. Can vectors acting in opposite direction be equal? Explain. */2/*

3.4. Mmoelo is applying a force of 768 N on the wall, but the wall does not move or shake. What is the resultant force in this action? Explain your answer. */2/*

3.5. There are two methods of determining the resultant vector graphically, (1) Tail – to – head method and (2) Parallelogram method. Describe the two methods fully.

/4/

This question demanded more explanations from learners. It was pleasing that most of the learners were able to answer Question 3.2.and 3.3 well. Below is a table of how some learners answered this question.

Table 8: Some responses from learners to Question 3.3:

Statement / Response	**Learners responses**
No it depends on their size	L1R
Resultant vector is acting in the direction side	L2R
No because the points will be not on same place	L3R
They are acting in negative direction but equal because they have horizontal line and vertical	L4R

The vector acting in opposite direction be equal it have the change direction scalars	L5R
Yes, because direction shows both sides	L6R
Yes, because is the same line space	L7R
Yes, because their signs are not the same and the magnitude is the same	L8R
Yes, because they are having the same direction	L9R
No, because the vectors are working with distance	L10R

The sub-question 3.3 was answered fairly well. The learners showed some understanding of vectors acting on a straight line. I was also pleased with those who answered *No* because they provided reasons for their answers. Generally this question revealed the reasoning capacity of the learners.

Question 4 asked the learners to transcribe their knowledge about vectors into graphs and diagrams. Below is an extract of Question 4:

4.1. The two forces F1 and F2 act from the same point. F1 is 20N to the West and F2 is 50N to the South. Use a scale of 10 mm: 5 N to draw the graph of these forces. /3/

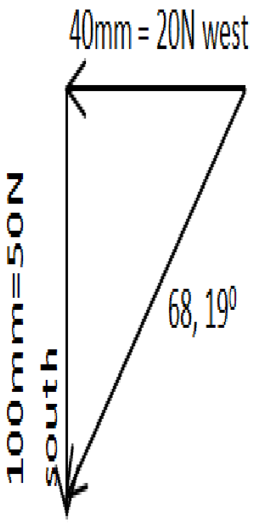
4.2. Which theorem would you use to calculate the resultant of these two forces? /1/

4.3. Use the theorem you mention above in 4.2, to calculate the resultant of these two forces. /4/

4.4. If the resultant force is making an angle of θ with the F1, calculate angle θ. /3/

Most of the learners were able to answer this question. They could draw the diagram of vectors. What impressed me was that most of them were even able to indicate the direction by arrows. The problem of indicating direction by arrows was mentioned in Chapter One where examiner's reports had stated that some Grade 12 learners could not indicate the direction when drawing vectors (momentum). An extract is shown below from some of the drawings learners gave.

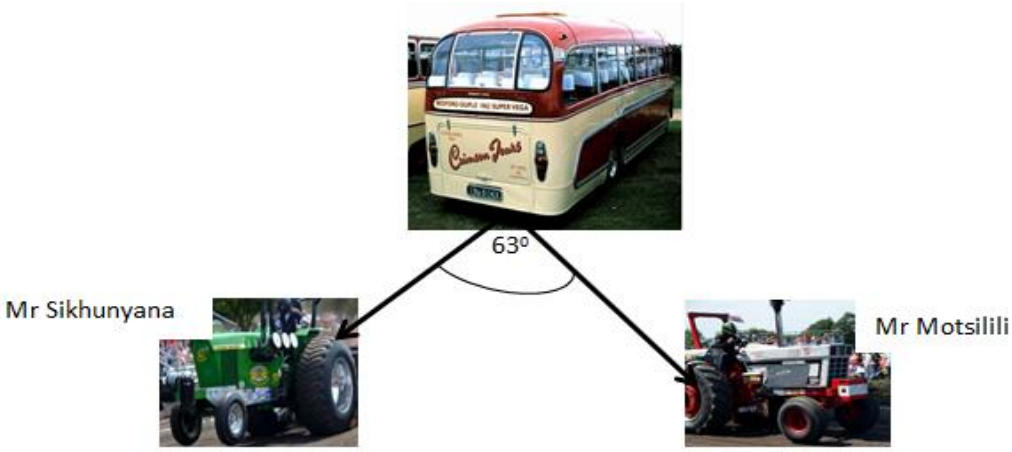
Table 9: Some responses from the learners to Question 4.1:

Statement / Response	Learners' responses
Scale 10mm = 5N $\quad F_2 = 50N$ South ; $F_1 = 20N$ West $10mm = \frac{5N}{20N} = \frac{1}{4}$ $\qquad 10mm = \frac{5N}{50N} = \frac{1}{10}$ 40mm = 20N West $\qquad$ 100 mm = 50 N South  	L1R

In Question 4 the learners were also able to display their understanding about the scale drawing and of units. Most of the learners did conversions well using the proportionality method (see also Appendix H).

In Question 5 most of the learners could not transcribe the figure into vector diagrams. This question required the learners to apply the parallelogram method. Below is the extract from Question 5:

1. *The two tractors are pulling a bus stuck in the mud. The first tractor is using a force of 1200N and the second tractor is pulling with the force of 800N. The angle between their chains is 63^0.*



2.

Use tail – to – head method to determine the resultant force of the two tractors.
[Scale of 10mm: 200N] */4/*

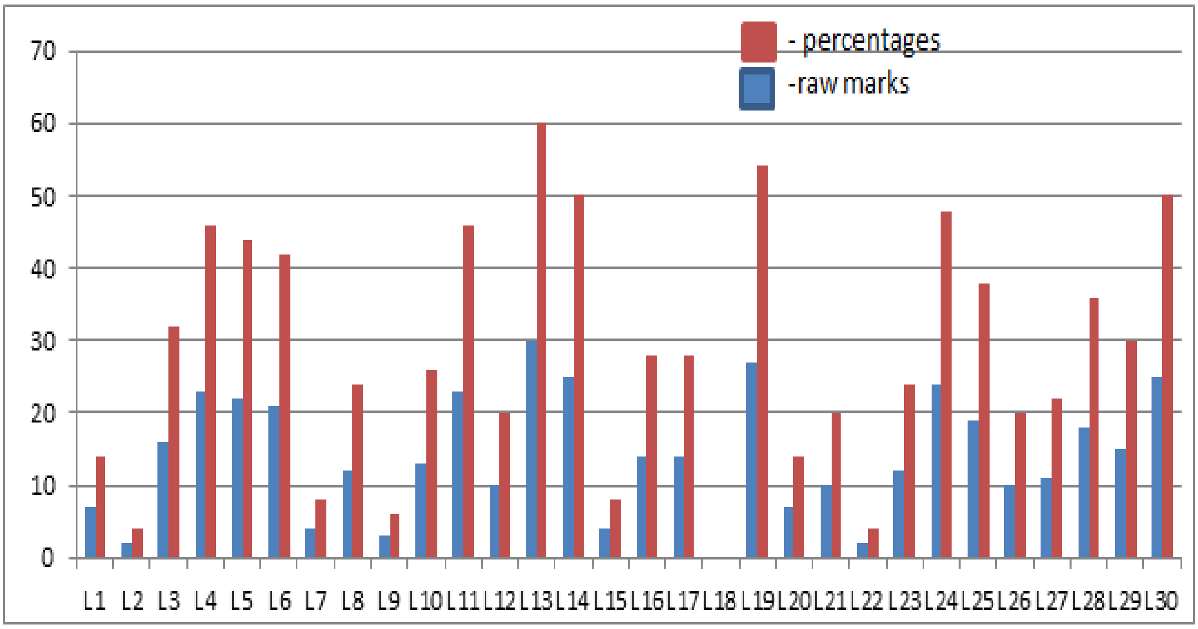
3. *The two men are pulling a tree in one direction while the third one is chopping it down. The ropes make an angle of 37^0. The first man pulls with a force of 480N and the second one is pulling with a force of 320N. Use a scale of 1cm: 40N and a parallelogram method to determine the resultant force of two forces.*

/5/

The challenge which was faced by the learners in this question was that of measurements and how to measure an angle of 63^0. Even though most learners performed poorly, a few made good attempts.

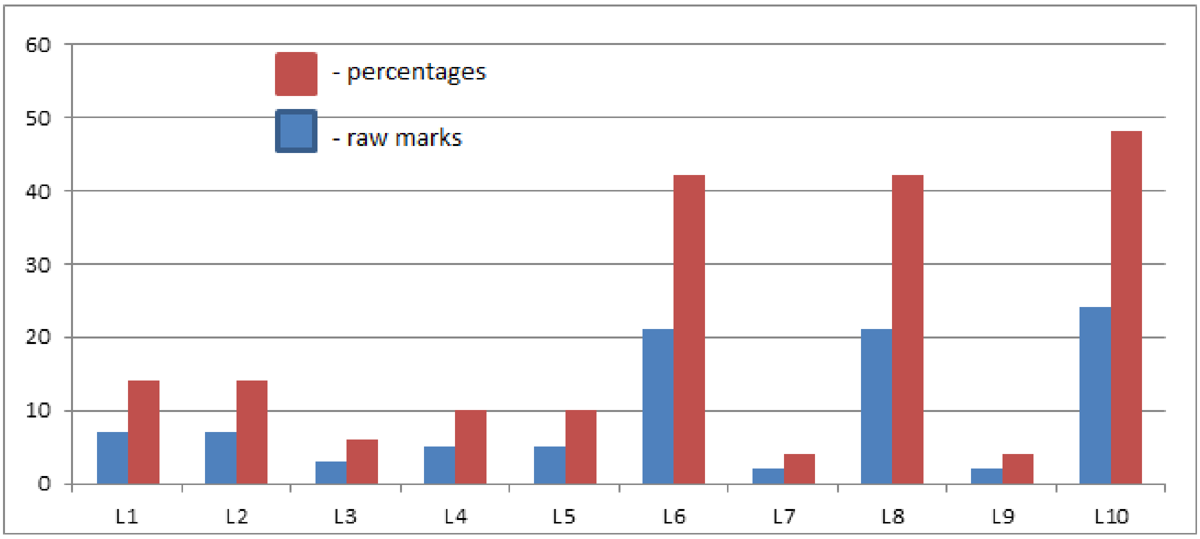
The overall performance on this summative test was not satisfactory. If time had allowed, I would have gone through the test with the learners and revised it. In general, it was clear that remedial work was needed. The results were also analysed and discussed with the teacher (T1) who agreed with the assessment and promised to do some revision work with the class before they wrote their end of the year final examination. Below is the summary of marks of the whole class.

Figure 3: Performance in terms of marks and percentages of all learners:



From Figure 3 above, it can be seen that most of the learners scored below 50%. One learner scored zero, see L18 above. How the focus group performed was examined separately as shown in Figure 4 below.

Figure 4: Performance in terms of marks and percentages of the focus group:



The focus group also reflected the poor performance of the class as a whole. All of the 10 learners who formed the focus group got below 50%. To dig deeper into the cause of this poor performance, stimulated recall interviews had to be conducted.

Reflections on summative test

The learners performed fairly in the summative test although it later appeared that language was a challenge. I noted that some of the learners could not score high marks due to a lack of understanding. Another limitation which might have contributed to the poor performance was that the learners were not given much time to prepare for the test. Also, the summative test being long and out of 50 marks might have had an impact on the results. For future research, these limitations should be corrected and avoided.

4.6 INTERVIEWS

One of the data gathering techniques was interviewing the learners (see Appendix I). In this interview six initial questions were asked. Follow up questions were also asked to strengthen and support the main questions. The interviews were intended only for the ten focus group learners. I decided to select only three of the interview results for discussion, these being the ones that I thought related most interestingly to the research questions and the sub-questions of my study.

4.6.1 Interview one

These interviews were conducted with individual learners. Hence I started with learner 1 (L1).

Q1*: "How did you understand the lesson on vectors as compared to other topics or lessons?"*

L1*: "I enjoyed the lesson very well. Miss (T1) was clear and more active on the first day you were there videotaping".*

FQ: "*What do you mean when you say, you enjoyed the lesson?"*

L1: "*She explained it very well. The demonstration you made of a parallelogram was nice".*

From the responses, it appeared that the learners did understand when the teacher was teaching but they understood better when demonstrations were used. As L1 said, she enjoyed the demonstration of the parallelogram method and resultant vector, shown below in Picture 6.

Picture 7: Demonstration of resultant vectors:

The two boys were simultaneously pulling the girl at an angle of 90^0. The findings: the girl moved away from neither of them, instead she moved forward. The forward movement represented the resultant of the two vectors. The learners enjoyed this demonstration.

Q2: "*Which part was more interesting? And which part was not interesting?"*

L1: "*I enjoyed the tail-to-head method".*

FQ: "*Why this method?"*

L1: "*It was easy because we were now actively involved. When doing something with our hands, boredom goes away".*

FQ: "*What about other methods?"*

L1: "*The parallelogram method was clear by the time you showed us that demonstration".*

This response also showed that the practical activities were more important. L1 emphasized that be saying it chased boredom away. This highlighted the importance of practical activities in Science.

Q3: "*Was there any link between Physics and Mathematics? What was it?"*

L1: "*Parallelograms and Pythagoras theorem…all that was Mathematics. And that part of tan…trigonometry".*

It was encouraging that the learners linked or were able to associate one learning area with another. L1 seemed to have understood this aspect of linking what was being taught to Mathematics. Integrating and linking across subjects, makes it possible for learners to make sense of their learning.

Q4: "*Was it the first time you learnt about vectors? If no, where and when did you learn about it?"*

L1: "*It was the first time".*

FQ: "*Didn't you learn about vectors or forces in Grade 9?"*

L1: "*We were only taught about the forces not vectors".*

It was true that vectors were only introduced in Grade 10. Equally important is that forces were taught in Grade 9 while in Grade 10 forces were considered to be vectors. This was a clear and good example of integration of subjects across the grades.

Q5: "*Would you like the teacher to repeat the lesson and why?"*

L1: "*Yes, I would. I am not clear about the drawing of a resultant vector from a parallelogram method".*

Seemingly there is never enough time available for learners to fully understand a concept. Although L1 said she enjoyed the lesson, she still wished the teacher could repeat the lesson. This is a challenge for all the theoretical lessons (those that are not practical or demonstrative).

4.6.2 Interview two

The interview with the learner 2 (L2) was different from that with L1 in that L1 was fluent in English and had arrived at our school from a former model C school. For that reason, her interview was conducted in English. L2 on the other hand, struggled a great deal with speaking English so her interview was switched from English to Sesotho. At the start, L2 was told to feel free to interact and respond to questions in Sesotho. The interviewer had to translate everything in the interview schedule into Sesotho.

Q1: How did you understand the lesson on vectors as compared to other topics or lessons? [Translated: *ha o bapisa di vectors le dithuto tse ding, o di utlwile jwang?*]

L2: *ha ke ya ka ka di utlwisisa ntate titjhere.* [Translated: I did not understand them at all sir.]

FQ: what about other lessons and topics taught before, how did you understand them? [Translated: *dilesson tse ding tsona o di utlwile jwang?]*

L2: *ee…tse ding ke ne ke di utlwisisa mara…divectors tsona ha ke ya di utlwisisa hantle.*

[Translated: ye…s other lessons I could understand but with the vectors, I did not understand.]

I sensed the problem of a language with this learner. He said he did not understand anything.

Q2: Which part was more interesting? And which part was not interesting? [Translated*: ke karolo efe ya divectors eo o bileng le thahasello ho yona?*]

L2: *di calculation tsona di ne di le thata haholo. Le testing mona ke di fositse kaofela.* [Translated: Calculations were very difficult. Even here from the test I got them wrong.

According to the responses of L2, nothing was interesting with the lesson. He did not tell me which part was interesting. But he told me of the difficulty of calculations.

Q3: Was there any link between Physics and Mathematics? What was it? [Translated: *e be e teng ntho eo o e boneng e tshwanang le ho amana le dipalo ha missi antse a ruta? Ha e le teng ke efe?*]

L2: *ee…e teng, mane moo ho buuang ka ditriangle…[*Translated: ye…s it is there, where it is talked about triangles.

Even though the learner could not understand a thing from the lesson, one of the senses was working positively. He could see the triangles and was able to associate them with Mathematics. This also supports that demonstrations and illustrations are very important during the learning situation. Indeed, the teachers' presentations should cater for most of the five senses if not all.

Q4: Was it the first time you learn about vectors? If yes, where and when did you learn about it? [Translated*: e be …e ne e le la pele o rutwa ka di vectors? haeba e se la pele, e ne e le ho kae , hona neneng?*]

L2*: e ne e le la pele ntate titjhere.* [Translated: it was the first time sir.]

FQ: *ha o ya ka wa bala ka di forces kapa di vectors ha Grade 9?* [Translated*: Didn't you learn about vectors or forces in Grade 9?*

L2: *tjhee…ntate mosuwe ha ke hopo…le. Empa di force re ne re bala ka tsona ha Technology.* [Translated: no… sir I don't reme…mber. But we learned about forces in Technology]

This learner seemed to be remembering nothing of what was taught in Grade 9. However, he remembered that in Technology they were learning about forces. He is the one of those learners who aged 20. He was even condoned to move up to Grade 10 from Grade 9. On reflection, we can't put all the blame on the learners' shoulders.

Q5: Would you like the teacher to repeat the lesson and why? [Translated: *O ne o ka lakatsa ha missi a ka pheta thuto ee ya di vectors hape?*]

L2: *ee…ya sir. Nka thabela ha a ka e pheta lesene ena ya di vectors. ha ke ya ka ka e utlwisisa hantle.* [Translated: yes sir. I would love her to repeat the lesson. I did not understand them well.]

It was clear from these responses that L2 would have liked the teacher to repeat the lessons. He had obtained a low mark (14%) on the summative test. If time allowed, L2 would need an individual attention from the teacher.

4.6.3 Interview three

Learner 3 (L3) spoke *isiXhosa* and she preferred to be interviewed in that language. So the interviewer had to switch from English and *Sesotho* to *isiXhosa* during the interview and re-adjust the interview schedule accordingly.

Q1: How did you understand the lesson on vectors as compared to other topics or lessons? [Translated: *Uye wasiva njani isihloko malunga nevectors xa usingqamanisa nezinye izifundo?*]

L3: *Ndafumana ubunzima.*Translated: [I found it difficult]

FQ: *Yintoni eyayinzima?* [Translated: what was difficult.]

L3: *Utitshalakazi waye khawulezisa xa ethetha. Bendishiyekela mna……*[Translated: Miss was fast in talking. I was being left behind.]

A common factor with L3 and L2 was their difficulty with the language of teaching and learning. L3 complained that the teacher was talking too fast and that she was left behind during the lesson.

Q2: Which part was more interesting? And which part was not interesting? [Translated: *Yeyiphi nto eyayinika umdla kwisifundo nge - vectors? Yintoni eyayinganiki mdla?*]

L3: *Yayingulamzekelo weparallelogram. Xa usibonisa iresultant.* [Translated: That example of parallelogram when you were showing us the resultant]

FQ: *Yeyiphi enye indawo eyakunika umdla?* [Translated: Which other part was more interesting?]

L3: *kuphela mfundisintsapho.* [Translated: It's only that sir]

From the responses of L3, it is clear that this learner, like L2, had a problem with the language of instruction. She was even hesitant when answering my questions. Language barrier could be the reasons why these learners failed the summative test. They did not understand well during the lessons.

Q3: Was there any link between Physics and Mathematics? What was it? [Translated: *Ingaba belukhona na unxulumano phakathi kwesifundo senzululwazi kunye nezibalo?Ngowuphi umahluko?]*

L3*: Ewe mfundisintsapho ukhona.* [Translated: yes, sir there is.]

FQ: *Ngowuphi?* [Translated: which one is that?]

L3: *Izibalo.* [Translated: In calculations]

FQ: *Yintoni ibibalwa apho?* [Translated: what was being calculated there?]

L3: *Xa besibala iresultant vector.* [Translated: when we were calculating the resultant vector].

The learner was not relaxed. Even though the interview was in her home language, she could not answer my questions in a pleasing manner. It seemed that the issue of language could deeply hinder the learning of the child.

Q4: Was it the first time you learn about forces or vectors? If yes, where and when did you learn about it? [Translated: *Ingaba ibilityeli lokuqala ufunda ngevectors? Ukuba ewe, phi kwaye nini ubufunda ngayo?*

L3: No sir…*bendingaqali*. [Translated: no sir….it was not for the first time.]

FQ: *Wawufunda phi ngazo*? [Translated: where were you learning about them?]

L3: Kwibanga lethoba (grade: 9) *sifundile* ngeforces. [Translated: In Grade 9 we learned about forces.]

FQ: *Kwakusithiwani* ngeforce? [Translated: What was it about forces?]

L3: Force is a pull or a push

Even though the interview was not easy for L3, it seemed that she had been taught about forces in Grade 9 and she knew the definition of force as 'a pull or a push'.

Q5: Would you like the teacher to repeat the lesson and why? [Translated: *Ubunganqwenela ukuba utitshalakazi asiphinde* esi sifundo ngevectors?]

L3: *Ewe mfundisintsapho. Dingavuya ukubangaba utitshalakazi angayiphinda*. [Translated: Yes sir, I can be happy if Miss can repeat the lesson.]

FQ:Kungokuba *kutheni ufuna ukuba asiphinde isifundo*? [Translated: why…? Why do you want her to repeat the lesson?]

L3. *Ukuze ndizive kakuhle mfindisi* ivectors ezi. [Translated: So that I could understand these vectors well.]

The learner was not relaxed. Even though the interview was in her home language, she could not answer my questions in a pleasing manner. It seemed that the issue of language could deeply hinder the learning of this child.

Q4: Was it the first time you learnt about forces or vectors? If no, where and when did you learn about it? [Translated: "*Ibi okokuqala ufunda ngevectors? Uba kunjalo, wawufunda nini, phi ngazo?"*]

L3: "*Bendingaqali*". [Translated: It was not for the first time.]

FQ: Where were you learning about them? [Translated: "*Wawufunda phi ngazo*?"]

L3: "*Kwa Grade 9 sifundile ngeforce"*. [Translated: In Grade 9 we learned about forces.]

FQ: What was it about forces? [Translated: "*Kwakusithiwani ngeforce?*"]

L3: Force is a pull or a push.

Even though the interview was not easy for L3, it seemed that she had been taught about forces in Grade 9 and she knew the definition of force as 'a pull or a push'.

Q5: Would you like the teacher to repeat the lesson and why? [Translated: "*Ubunganqwenela ukuba umisi ayiphinde ilesson ngevectors*?"]

L3: "*Ewe mfundisi. Dingavuya ubangaba angayiphinda*". [Translated: Yes sir, I can be happy if Miss can repeat the lesson.]

FQ: Why? Why do you want her to repeat the lesson? [Translated: "*Ngobaa? Kutheni ufuna ukuba ayiphinde le lesson?*"]

L3. "*Ukuze ndiziunderstande kakuhle mfindisi ivectors ezi".* [Translated: So that I could understand these vectors well.]

All three of these interviewees wished that the lesson could be repeated, especially those learners who had a problem with the language of instruction. It seemed that the problem was more with the language than with anything else. This is really an intractable problem because language is the most prominent tool for sense making.

4.7 REFLECTIONS ON THE INTERVIEWS

The interview schedules suffered the limitation of the researcher not having had enough time to pilot it. As a result, some irrelevant questions were not eliminated. The interview schedule originally had eight questions which were reduced to five. Also the background of the interviewees needed to be taken into consideration. The interview schedule needed to be designed to cater for the language of the interviewee. In this study, the questions had to be translated during the process of interviewing.

4.8 CONCLUDING REMARKS

In this chapter, the data generated using four data gathering techniques described in Chapter Three were presented and analysed. The initial diagnostic test showed how far and how much knowledge learners had with regards to resultant vectors. The four lesson observations built a picture of how learners interact during lessons. They showed that the learners enjoyed learning through hands-on and practical activities. In follow-up interviews, the learners managed to indicate some of the challenges they were facing. It emerged that in science lessons, learners were facing challenges with the language of instruction. The data revealed a picture of how teaching and learning should be in order for sense making of learning to take place. In the next chapter, this picture is interpreted and discussed.

CHAPTER FIVE

INTERPRETATION AND DISCUSSION OF FINDINGS

5.1 INTRODUCTION

In this chapter, I interpret and discuss the findings on how Grade 10 Physical Sciences learners made sense of the resultant vector concept in the learning and teaching situation. The findings discussed in this chapter were derived from four data gathering techniques used, namely, the diagnostic test, lesson observation, a summative test and stimulated recall interviews.

The diagnostic test was administered to the whole class for the purpose of understanding the learners' level of knowledge in relation to resultant vectors.

Lesson observation offered an opportunity to gather 'live' data occurring in a social situation, which in this case was a classroom. After the lesson observations, a summative test was administered to the whole class in order to assess the learners' understanding. A focus group was selected for an in-depth analysis of the test as well as for interviews.

Interviews were conducted with six of the focus group members, however only three transcriptions from the interviews are presented. The discussion is further underpinned with literature and personal viewpoints. In discussing the findings I also present and discuss the themes that emerged during the data gathering process.

For ready reference, the main question and sub-questions of my study are repeated here. The goal of my study was to investigate how Grade 10 Physical Sciences learners made sense of the resultant vector concept. To accomplish this goal, I sought to answer the following main question:

- How do Grade 10 Physical Sciences learners make sense of resultant vectors?

The following sub–questions were used to help me answer the above main question of the study:

- What prior knowledge do Grade 10 Physical Sciences learners have on the topic of resultant vectors?

- What kind of learning mediation is required to help learners make sense of the topic of resultant vectors?
- What are the challenges encountered by the Grade 10 learners in calculating resultant vectors?

The major themes and analytical statements that emerged in response to these questions are summarized in Table 10 below, organized with their data sources. In some cases, responses have already been presented in short summaries or discussions (see Chapter Four). It was not always possible to present what emerged in terms of percentages and I had to be selective when it came to all learners' responses, but where appropriate the points that seemed particularly relevant to my study were considered.

Table 10: Major themes and analytical statements:

Data source	**Theme**	**Analytic statement**	**Theory**	**Research question(s) addressed**
Diagnostic Test	Prior Knowledge	Integration of prior knowledge and new knowledge across the Grades.	Social constructivism	1
Lesson Observations	Learning approaches	Learning through practical activities and demonstrations	Sense making	1 & 2
Summative test	Mathematical skills	Integration of Mathematical skills to Sciences	Assessment	2 & 3
Stimulated recall interviews	Language of learning and teaching (LoLT)	Language as an issue in learning.	Sense making	1, 2 & 3

5.2 DISCUSSION OF THE FINDINGS

5.2.1 Analytical Statement 1: Integration of prior knowledge and new knowledge across the grades

According to Dewey (1938), experiential learning is important and experience is the basis of most teaching and learning. Experience is always referred to as the 'past', and it is what constitutes prior knowledge. So, we cannot talk of knowledge if someone is without an experience. Therefore, diagnosing the prior knowledge of learners through a test was important in this study. Although in Grade 9 the learners were taught the definition of forces only, that is enough to form the basis of an understanding of vectors. The responses of the learners on the definition of forces reflected that they did have knowledge, which could be used as a foundation for the learning on vectors.

Dewey (1938) also emphasized that inquiry involves the continuous reflection of experience from the past (*á posteriori* knowledge). This means that knowledge is always acquired in the context of past experience. In Grade 10, the learners were going to be taught about vectors using forces as examples of vectors, and they had supposedly been taught about forces in Grade 9. The knowledge from Grade 9 was now integrated into the learning of Grade 10.

The diagnostic test did not reflect only the learners' prior knowledge but also where they were lacking in terms of general knowledge and experience and this was a response to sub-question 1 of the study. For example, the learners could not add or subtract forces acting on a straight line. This gave the researcher information and a sense of what to expect in the ongoing study.

From the learners' written responses, I also got a sense of whether learners were able to distinguish between their everyday language and science language. One learner gave the definition of force as: *The ability to do something, force up or down*. This learner then had some knowledge about force in mind. In our everyday language, we talk of forcing things. Anything that is exerting a pressure is referred to as 'force'. In everyday language, to squeeze is to 'force'. The concept of pressure was not frequently used; instead 'force' was used in place of pressure. This was an indication of how everyday language can hinder or constrain learning of scientific language. Language plays an important role in assisting learners to construct the relations between informal knowledge and scientific knowledge (Capps & Pickreign, 1993). This means that misconceptions in acquiring knowledge and mistranslation of concepts from one language to another may distract from the learning of new concepts.

In response to the question as to when forces can be added or subtracted (SQ1.3 of the diagnostic test), one learner wrote: *When an object needs more force we add force*. This is an everyday spoken language usage. This is an area that teachers need to address in order for the learners to make sense of their learning. To limit any misconceptions, learners must be taught to distinguish between scientific knowledge and everyday knowledge. For an example: the learners know that a *force is something to force things up or down.*

The learners' prior knowledge also presented an opportunity for me to identify those learners who were repeating Grade 10. Intentionally, a question was asked to define a vector. About seven learners were able to answer it correctly. On interacting with the learners, I discovered that those seven learners were indeed repeaters. The new learners from Grade 9 were unable to define vectors. Another usefulness of a diagnostic test is to help the teacher to plan the lessons accordingly. If there are repeaters in class, that helps the teacher in grouping the learners in class. The repeaters might be used as MKOs and peer teachers.

The lesson learned from administering a diagnostic test was that it gave the teacher a picture of what kind of learners there were in class. It also helped reveal the level of the learners' knowledge in relation to what was to be taught. The learners' misconceptions were identified through their taking a diagnostic test. Prior knowledge of the learners is the main reason for conducting a diagnostic test. Le Grange (2007) argues that the socio-cultural experience the learner brings into the classroom is a vital tool to use to enable learners to perform well in school science.

5.2.2 Analytical statement 2: Learning through practical activities and demonstrations

This section discusses the importance of practical activities and learning from demonstrations in making sense of scientific concepts, as elicited from the class room observations. The approach to learning helps determine how much and how learning takes place. Wood, Bruner and Ross (1976) suggest that teachers should help or support and motivate the learners to recall what they have learned in the previous grades so that they can easily make sense of the next grade's knowledge. This means that teachers should not only introduce totally new content knowledge to the learners, but that the content presented must always be relevant to the contextual background of the learners in order to keep learners actively involved.

Because the topic on vectors is abstract, there were moments of passivity and moments of activeness during the lessons. Passivity is referred to here, as the moments of teacher-talk only and learners quietly listening (see Picture 2 in Section 4.4). The way the learners are listening and their facial expressions show that something new is being presented to them.

Learning approaches gave me a sense of how learners make sense of their learning. Effective sense making will depend on how the content to be learned is presented. Good presentation of the content yields more sense making on the part of the learners. In line with that, too much theoretical presentation of the content leads to a dull class. The picture 2 in section 4.4 above, explains this scenario well.

As I indicated above, there were also moments of activity, indeed this was eminent when the teacher began to do practical activities with the learners. The learners started to be active and participated in the form of asking questions (see picture 3 in Section 4.4.1 above). This means that even though the topic might be highly abstract, the teacher should try to use visual stimuli for the benefit of the learners. This could be in the form of charts, diagrams, demonstrations and practical activities. One of the learners commented that she understood better when things were done practically. Learning by doing is vital in sense making. The learners must be given the opportunity to experiment for themselves. In other words practical activities and hands-on activities are the most important agents of sense making.

It was also observed that the learners were more actively involved during the conversions of units when they scaled Newton's using a millimeter scale. The activity of drawing and measuring the length of vectors was interesting to learners. During this session, there was a shift from teacher-talk to learner-talk as illustrated in the circled learners in Picture 8. Although the orientation shifted, the teacher's role was still that of scaffolding those learners who could not draw the vector diagrams.

Picture 8: Learner-learner interaction and talk

Active involvement is realized through teacher-learner interaction in interpreting the world (Lemke, 1990). Lemke highlighted that learning science involves learning how to talk science meaningfully. He suggested that to talk science means learning to use specialized conceptual language for reasoning and problem solving, which many teachers find challenging. He also clarified that learning science means developing the capacity to communicate in the language of science and act as a member of the community of people who do so. For the discussion processes to succeed, however, learners need to enter into a discussion, that is, a 'shared enquiry' with one voice answering another. This shared inquiry is what I observed when the learners were discussing and helping one another in drawing vector diagrams. This would also concur with Wegerif (2006, p. 60) who posited that "teachers need to teach learners how to engage in the discussions through which knowledge is constantly being constructed, deconstructed and reconstructed". That is, teaching and learning must be biased towards learner-centeredness as proposed by the social constructivists (Vygotsky, 1978).

Practical activities and demonstrations also serve to promote conducive learning environments when properly planned. In this study, the learners even began to engage with the teacher through questions. Learner engagement in a learning situation means that the learners have now taken ownership of the learning. Ownership of learning can result in sense making of the learning. One of the questions a learner asked was: "*Why do we have to choose on our own which direction is to be positive or negative when dealing with vectors*?" The learner asked this question referring to a textbook example. The example in the textbook was referring to the convention of upward motion as positive and the downward motion as negative. On the contrary (the learner's point of view), the teacher was saying we may choose which direction to be positive or negative. This picture above shows more engagement by the learners. The teacher clarified the misconception and the learners' understanding was improved.

The practical activities were also characterized by the flexible switching of language. The learners tended to switch to their home language when interacting. Even the questions the learners asked were mostly in their home language. This raised the issue of the role of language in learning. The teacher was flexible enough to allow her learners to interact in their home languages which were *isiXhosa* and *Sesotho*. This was helpful as it is one of the factors that help the transition from teacher-talk only to teacher-learner-talk as proposed by Lemke (1990). Interaction between the teacher and the learners was improved as the learners were now speaking their home language. Language plays an important role in assisting learners to construct the relations between informal knowledge and scientific knowledge (Capps & Pickreign, 1993). During the mutual interaction between the learners themselves and their teacher in their home language, sense making was possible.

One lesson learnt from the lesson observations was that practical activities are very important during learning situations. The learners became passive when there was no practical activity taking place. The teachers must try to contextualize their lessons as much as possible. The teachers also have to cater for the language level and background of the learners. Most of the times teachers of science find themselves code switching in an endeavor to make learners understand what is being taught (Probyn, 2004). Code switching simplifies the language, so there is no way that sense making can effectively take place without a language that is adequately understood by the learners.

5.2.3 Analytical statement 3: Integration of mathematical knowledge in science

What is taught during Mathematics lessons should be integrated into Physical Sciences lessons. This will enable the learners to deal with concepts that are mathematically orientated. If this is not done, learners will find it difficult to do calculations. The challenge of Physical Sciences learners lacking mathematical knowledge was prominent during the lesson observations and the summative test. It was difficult for the learners to work with measurements and conversions using the given scales. They struggled to represent Newtons as length using a given scale. This lack of mathematical knowledge was a hindrance to learners' making sense of scientific content.

It was noticed during classroom observations that the teacher spent almost one whole lesson explaining mathematical concepts and calculations. For example, 'measurement' is a topic for Mathematics in Grades 6, 7, 8 and 9 but when the learners came across measurement in a different subject that was not Mathematics; they found it difficult to understand the application. The basics such as measuring with a ruler are taught or at least expected to be taught in the lower grades. As a result, Physical Sciences teachers have to re-teach these mathematical basics before they can introduce their scientific concepts.

Mathematical skills that were really problematic during the lesson observations were eminent in the conversion of the units. The teacher spent almost 45 minutes of the period explaining the process of converting one representational unit to another. When graphically representing forces which are measured in Newton's (N) as the length of a vector which might be measured either in millimeters (mm) or centimeters (cm), there must be conversion of units.

For the learners to be able to convert units, a scale must be given. Conversion according to a given scale is a topic that is supposed to be taught in Grade 8 Mathematics (CAPS), but it was found that learners arriving in Grade 10 had not been taught about this. This poses a challenge when they are supposed to integrate that knowledge into science. This retards the progress in learning.

In the summative test there were a lot of calculations required. The assessment showed that the learners still could not apply Mathematics to solve problems with resultant vectors. They got most of the questions wrong especially those involving calculations. This challenge of not integrating mathematical skills into science confirms what Funda, William, Robinson and Mark (2008) say when they state that Physics requires good mathematical skills and that Physics cannot be learned without a mathematical background. They highlighted the importance of competency in Mathematics in order to be competent in other related sciences subjects like Physical Sciences. After observing the lessons and conducting the summative test, I now concur with them that competency in Mathematics is important for Science. In one question where learners were asked to calculate the resultant vector using Pythagoras theorem, it was found that they could not apply the theorem in order to calculate the hypotenuse side of the triangle. Although the question stated that the forces are acting perpendicular to one another, one learner gave the answer equivalent to $F_{res} = F_1+F_2$. This clearly showed a lack of mathematical knowledge on the part of these learners.

The other challenge observed was that the learners could not convert statements into mathematical expressions. In his study, Ogunleye (2009) also found that learners were unable to construct meaning from the problem statement. This challenge that the learners faced in Mathematics, also affected their performance in Science. For example, when the question said, 10mm to the East and 15mm to the South, the learners could not recognize that these vectors were perpendicular to each other or were acting at 90^0 to each other. Those who were able to draw the perpendicular vectors could not work with squares and square roots. One learner wrote the Pythagoras theorem formula as if $r^2 = x + y$; the squares were left out. Competency in Mathematics as a supporting knowledge for sciences is required for learners to make sense of their learning.

This is how one learner worked out the resultant vector:

$$r^2 = x^2 + y^2$$
$$r^2 = (37)^2 + (63)^2$$
$$r^2 = \sqrt{1369} + \sqrt{3969}$$
$$r^2 = 37 + 63$$

If learners are unable to work with vectors acting at 90^0 to each other, they will most likely struggle more with vectors acting at arbitrary angles to each other. They are also unlikely to be able to calculate the resultant vector using the parallelogram method. Indeed, no learner was able to attempt the last question of the summative test. Furthermore, the learners could not construct and complete the parallelogram method. The other challenge the learners faced was to measure an angle of 63^0 by means of a protractor. The whole class could not attempt this question.

These experiences showed that the learners' prior knowledge was very important for them to understand the new information taught. Knowledge from other subjects as well as from other grades is very important. Integration of knowledge across the subjects and across the grades can help learners make sense of concepts. In other words, the knowledge gained from Mathematics must be applicable to Science or other subjects. Wood, Bruner and Ross (1976) suggest that teachers should therefore help learners to recall what they have learned in the previous grades so that they can easily make sense of the next grade's knowledge. It is important that the teachers help learners to remember and recall what they have learned from the previous grade. Likewise, learners must be prepared for the next grade. They can help themselves to do this by anticipating the content of the next grade.

5.2.4 Analytic statement 4: Language of learning and teaching (LoLT): language as an issue in learning

One of the common factors that hinder sense making by learners is that of the language of instruction. In our schools, particularly the one where this study was conducted, the language of learning and teaching (LoLT) is foreign to both learners and teachers. That is, both learners and teachers are second language English speakers.

Language serves as a means of communication between teachers and learners. It is a medium through which the teachers convey the content knowledge to the learners. On the other hand, the learners use the same language to respond to the teachers if they have received the message. This means language is equally important to the teachers as well as to the learners. This also signifies the importance of strategic lesson planning by the teachers.

The language level and the home background of the learners must be taken into consideration in the planning and preparation of the learning materials and the lesson plans. Language plays an important role in assisting learners to construct the relations between informal knowledge and scientific knowledge (Capps & Pickreign, 1993). It is through language that the teachers translate the scientific terms or concepts to simple terms, the terms that can be understood by second language speakers of English. Language also enables the understanding of scientific concepts in the teaching and learning of science. Hence, poor performance of learners in the subject is often attributed to language.

During the interviews conducted with the three learners, two preferred to be interviewed in their home language. They cited as reasons that they felt comfortable with their home language. Only one learner was comfortable to be interviewed in English and she had previously been schooled at a former model C school. As a result, she was even more fluent in English than her home language.

Regarding the interviews conducted in the vernacular, the researcher had to translate the whole interview schedule into *Sesotho* for the second interviewee and into *isiXhosa* for the third one. If learners are struggling to speak English, how could they be expected to understand what they are being taught? The social constructivist perspective adopted for this study is characterized by interaction between learner-learner and teacher-learner and in the process of interaction language plays a key role (Lemke, 1990). Lemke explains that "learning science means learning to talk science" and language represents an important barrier to learning for many learners. So, if language does not play that effective role, no proper interaction will take place. Hence, there will be none or very little sense making by learners.

Moving on from the issue of language, the issue of calculations re-surfaced when interviewee one raised the concern that she could not understand the calculation of resultant vectors. She found it a challenge to use a scale to convert millimeters to Newtons and back. The other two learners said they did not understand the lesson on vectors. One said "*Umisi uya khawuleza xa ethetha"* [Translation: Our Miss talks very fast]. It would be fair to say that they did not understand due to their lack of proficiency in LoLT. When the teacher continued to explain in English, most of the learners were left behind. This was evident from their performance in the summative test which clearly showed that the learners could not understand the lessons on resultant vectors.

It was confirmed that competency in the LoLT played a role in the sense making of the learners. The reason for many learners failing was not because they did not know the answers, the challenge was that they did not understand the questions. The language used to present the questions was the issue that caused the problem. This was further justified through analysis of the performance in the summative test results. Those learners who were perceived not to be proficient in LoLT, did relatively poorly in the test. On the other hand, those fluent in English (LoLT) did better in the test. The learner who preferred to be interviewed in English scored about 42% while the two learners who preferred to be interviewed in their home language, scored very low; the *isiXhosa* speaking learner scored about 10% and the other *Sesotho* speaking learner scored just 4%.

5.3 CONCLUDING REMARKS

In this chapter, I interpreted and discussed the findings generated from the diagnostic test, observations, the summative test and stimulated recall interviews. From the analysed data sets, I came up with four analytical statements. Through these statements, the data were able to speak for themselves as to how the teacher was providing support to her learners in making sense of the concept of the resultant vector.

The analytical statements expressed the importance of prior everyday knowledge of the learners. The learners made sense of scientific knowledge when they were able to link what they learned to what they already knew. So, it is very important for teachers to take into consideration learners' prior knowledge during their lessons.

It also emerged from the findings that the learners were finding it challenging to be taught in English, which is the medium of instruction. Therefore, teachers need to take into consideration the language gap of the learners. Naturally it is difficult to understand what one is being taught if is it is presented in a language foreign to one.

The next chapter provides a summary of the findings of the study which culminate in recommendations and suggestions for future research, the limitations of the study, critical reflections on the research journey and the conclusion.

CHAPTER SIX

SUMMARY OF FINDINGS, RECOMMENDATIONS AND CONCLUSION

6.1 INTRODUCTION

This chapter presents a summary of the findings of the study into how Grade 10 Physical Sciences learners make sense of resultant vectors. It then suggests some recommendations that could help the learners to make better sense of this subject. These recommendations could hopefully constitute an effective mechanism for scaffolding learners, especially in making sense of resultant vectors and concepts through creating and sustaining an enabling environment. Finally, the chapter makes some general recommendations, discusses limitations of the study, areas for future research and offers some critical reflections.

6.2 FINDINGS FROM DATA GATHERING TECHNIQUES

Below is the discussion of the findings from each of the data gathering techniques.

6.2.1 Diagnostic test

The diagnostic test was helpful in that it provided a glimpse of the prior knowledge the learners had before being taught the material on vectors in Grade 10. It was found that in Grade 9 the learners had been taught about forces and remembered that material. This was evident from the learners being able to define force. Forces are the examples of vector quantities used in Grade 10. If learners have an understanding of what force is, that can help them understand vectors better.

The results and performance of the learners in the diagnostic test were presented to the teacher and this enabled her to plan her lessons accordingly and to do remedial work of the content of Grade 9 before introducing the topic on vectors. The rationale was to place learners at the same level of understanding in relation to forces. This was helpful because the intent was to make sure no learner was left behind.

6.2.2 Lesson observation

The lesson observations helped in answering sub-question 1: What prior knowledge do Grade 10 Physical Sciences learners have on the topic of resultant vectors? And sub-question 3: What are the challenges encountered by the Grade 10 learners in calculating resultant vectors?

It could be argued that the two sub-questions were answered well because the way the learners responded to the teaching of the topic on vectors was refreshing. For instance, the learners were actively involved in the lesson by seeking clarity and responding to the teacher's questions. From the lesson observations, it was found that the combination of the learners' prior knowledge and their level of understanding can influence the way mediation of learning should take place (Vygotsky, 1978). This was evident when the teacher was forced to change her lesson of the day due to the needs of the learners. The learners needed baseline knowledge of what the teacher was to teach. This was necessary for the learners to make sense of their learning.

I also found that it was important to allow the learners to learn at their own pace. When the teacher's pace was considered too fast by some learners, they were left behind. When learners learn at their own pace, they will make sense of their learning more easily. However, teachers have to control their pace and guard against being derailed by the learners from the plan of the day. During some of these lesson observations, the learners were completely derailing the teacher's plan and lesson. For an example, in one of the lessons the teacher spent almost an hour explaining something that was not in her lesson plan.

The lesson observations also highlighted the importance of practical activities in a Science class. The learners became passive when the teacher was explaining at length. On the other hand, given a chance to work on their own, they became active and lively. Some learners reported that they enjoyed the practical part of resultant vectors. This emphasised the importance of learner-talk in a science classroom (Lemke, 1990). The more learners articulate what they have learned, the more their conceptual understanding develops.

6.2.3 Summative test

The purpose of a summative test was two-fold. It served as an instrument to measure the degree of understanding the learners had and a measure of how much remedial work is needed. The results from the test showed that the learners had not understood well during the teaching process. This was reflected with the way they answered some of the questions from the summative test. For example, many learners were unable to answer the questions involving calculations.

Calculations are usually associated with Mathematics. The test also showed that learners could not transfer their mathematical skills in calculations to Science. The teacher was obliged to spend some time explaining and discussing this with the learners. The summative test also showed that the learners needed enough practice if they are to make sense of their learning. Teachers must allocate enough time for the learners to work on their own especially with regards to calculations.

6.2.4 Stimulated recall interviews

A stimulated recall interview is described as “an introspection procedure in which videotaped passages of behavior are replayed to individuals to stimulate recall of their concurrent cognitive activity” (Lyle, 2003, p. 861). However, in this study, the learners were presented with their marked scripts from the summative test and their verbal responses were elicited with regard to what they had written.

In an endeavor to validate the findings from the lesson observations and summative test, these kinds of interviews were worth conducting. The interviews were mainly based on the lessons conducted earlier and on the summative test the learners had written. This was to check the reasons for the generally poor performance in the test. Most of the learners interviewed explained that they did not understand what the teacher was teaching. Some said the teacher went too fast when teaching and talking. This further highlighted the issue of the language in a learning situation as described by Probyn (2004). The reason they did not understand was because of the LoLT being a weakly understood second language.

Language as such was not intended to be a factor under investigation in this study, but in the course of the research, it was found to be significant. Learners cannot make sense of scientific concepts if they are challenged in the LoLT and the language of science. Sense making by learners is made possible through language (Weick et al., 2005). Some learners could not understand English. For an example, several preferred to be interviewed in their home languages of *Sesotho* and *isiXhosa*. Some said they understood better the part that was done practically than the sections where the teacher was just explaining. From this, it was noted that hearing is not the only sense that should be used for learning; touching and seeing are equally important in sense making during learning and teaching processes.

6.3 CHALLENGES ENCOUNTERED

Lack of resources posed a challenge with the lesson observations. One camera was not enough for a class of 30 learners. The members of the focus group learners were seated at different places and angles in the class. So, one camera could not image all of them simultaneously. This means that not all the important information was captured during the observations. Another challenge was that of having an observer who is also the cameraman. Some notes could not be taken because the observer was holding the camera, thus inhibiting an important research tool.

Due to time constraints, the interview schedule was not piloted. As a result, some pitfalls were not identified. Out of the six interviewees, four requested to be interviewed in their home language. So, I had to translate the interview schedule from English to *Sesotho*. The other interviewees were *isiXhosa* speaking which also forced me to translate further from English or *Sesotho* to *isiXhosa*. In essence, language as an issue in education was also a challenge during the study.

6.4 RECOMMENDATIONS

When using diagnostic tests, I would recommend that the focus group be neutral and free of any learners who might be repeating the grade. This was overlooked before selecting the focus group. In this study, the learners who were repeaters could have distorted the data collected. This is because they appeared to recall some of things they learned the previous year. They had an unfair advantage over those new to the grade.

Another important point to note is that the outliers must be identified and omitted for data analysis. In the context of this diagnostic test, the learners who were repeating the grade scored high marks, which was quite misleading.

More than one camera would be needed to capture almost all the dimensions of the area to be observed. Lesson observations should also be piloted. This would make the participants at ease with the researcher. Equally important, the learners would get used to the cameras in their class. This means that the first two or so lesson observations may not be used for the purpose of the research or data gathering. It would be more convenient if the cameras could be mounted somewhere in the classroom so that they do not have to be carried or operated by a person. For example, three manually-operated cameras would need three additional people to operate them which would definitely create tension in the classroom. The observer should also be free from other tasks in order to take notes during the lesson observation.

I would also advise the teachers that lesson planning is important for effective learning to take place. Teaching of resultant vectors needs more demonstrations and practical activities. The teachers should not ignore the prior everyday knowledge of the learners. That is, the content to be taught should always be linked to what the learners already know. It is also important to integrate the content across the other subjects, for example, Mathematics, in the context of this study and across the grades.

Learners should be encouraged to ask questions and to be involved in discussions and constructive debates so as to improve their language proficiency in science classrooms. This could be done in conjunction with group activities, working in pairs or individual presentations in class. This could also improve learners' confidence and participation in science lessons. Through discussions by learners during this study, another opportunity for future research was observed: how to enhance learner-talk and argumentation during the science lessons?

If this study were to be repeated, I would be very careful with the setting of the interview questions, especially the follow-up questions. During the data analysis, I realized that there were gaps in the evidence produced, because I did not follow up. If I did, I followed up with the wrong questions. I also experienced problems accessing the Rhodes Library through off campus mode and often missed out on critical literature. I would also try to capture the voice of the learners; however, this was beyond the scope of this study.

6.5 AREAS FOR FUTURE RESEARCH

- A similar study could be conducted, but with an increased number of sample schools and learners included;
- Further research could be done on the appropriate methods of teaching in the second language in order for learners to make sense of the concept of the resultant vector;
- Further research could also be conducted on how cooperative learning can enhance sense making by learners;
- In addition, further research should be conducted on how effective lesson presentation can enhance sense making by learners;

- A study could be conducted on how practical activities could help learners make sense of their learning; and
- Finally, there is also a need for further research that would help strike a balance between ‘teacher-talk’ and ‘learner-talk’.

6.6 LIMITATIONS OF THE STUDY

Initially, I had planned to conduct this study at two different schools but due to financial, time and geographical constraints, the study had to be conducted in one school which was the school where I also teach. As a result, the findings could not be generalized. Nonetheless, it provided some insights into how Grade 10 Physical Sciences learners make sense of their learning.

Power relations also affected my study. At my school, I am a Head of Department (HoD) for Science and the teacher who I observed is in my Department. My presence in her class made her a bit tense. Even the learners were whispering to each other, “*The HoD is here to observe the teacher”*. That whispering alone could have had a negative impact on the outcome of the study. To allay the fears of the teacher, I had decided to develop a module and a unit of work together with her. This led me to be a participant researcher because I had to co-teach the module with her. This made her realize that the research focus was not on her but on the learners.

During the interview session, some learners were scared to tell me that they did not understand the lesson partly because they knew I was a HoD. I presume they did not want to talk badly about their teacher. From what they were saying, I could sense that they were hiding some of their feelings and this could have affected the validity of my study.

6.7 CRITICAL REFLECTIONS

It is true that a research study is a journey that needs to be taken with patience and resilience. I want to be honest here; it was very tough along the way. There was a point in time when I sent my colleagues a ‘What’s App’ message telling them about my withdrawal and my giving up the course. With their support and encouragement, I decided to carry on again. My wife also persuaded me to carry on with the course.

It was not an easy thing to investigate an abstract topic like this one and I struggled to access relevant literature on it. I realized that there is not much that has been written about the topic of resultant vectors and my study certainly contributes to closing this gap. Notwithstanding, the experience I got as a young researcher was enormous. I do not regret having carried out this type of study.

6.8 CONCLUDING REMARKS

This study highlighted the extent to which sense making by learners may affect their learning capabilities. The manner in which the lesson is presented to learners will also determine how far they go with understanding it. The study revealed the importance of integration of learning across the subjects and across the grades. This increases the context in which the learners make sense of their learning.

Language emerged as a major education issue during the study. I found that language competency in LoLT was a prime factor in making sense of the learning. The teachers must develop skills and teaching practices in the classroom geared towards second language speakers of English. The study also highlighted the critical importance of teaching using practical activities and demonstrations. This caters particularly for those learners who are challenged by the LoLT as they learn by seeing and touching as well as by listening to speech.

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Appendix A: letter to principal

MEHLOLOANENG LOCATION

P.O.BOX 1292

MATATIELE

4730

23 MARCH 2014

The Principal

KOMADIHARE SECONDARY SCHOOL

P.O.BOX 295

MATATIELE

4730

Subject: Request for permission to carry out a research study at School

I Tshepo Elliot Motsilili, a teacher at Komadihare Secondary hereby requests for permission to conduct a research study at your school as from 21 - 25 July 2014.

I have registered as a part-time student at Rhodes University, Grahamstown (student number 609m5602) as from January 2014 doing a Master's degree in Science Education. I would be most grateful if you would allow me to conduct my research study in your school.

My topic of study is "an investigation into how Grade 10 Physical Sciences learners make sense of the concept of the resultant vector: A case study".

The insights generated from this study will be published in a thesis form and will become accessible to the decision makers in education, curriculum developers, teacher educators and Physics teachers in order to bring about improved achievements in Science. Should I get permission, I will first subject the learners to a diagnostic test, observe and videotape four lesson presentations, subject them to a summative test and interview them (learners).

I assure the school and learners that everything will be treated confidentially and the participants reserve the right to withdraw. I will not use the real name for the school and the teacher.

Thanking you in advance

Yours Sincerely

Mr. TE Motsilili [073 1783 477]

Appendix B: letter to teacher

MEHLOLOANENG LOCATION

P.O.BOX 1292

MATATIELE

4730

23 MARCH 2014

The Science teacher

KOMADIHARE SECONDARY SCHOOL

P.O.BOX 295

MATATIELE

4730

Subject: Request for permission to carry out a research study with you and learners

I Tshepo Elliot Motsilili, a teacher at Komadihare Secondary hereby requests permission to conduct a research study at your school as from 21 - 25 July 2014.

I have registered as a part-time student at Rhodes University, Grahamstown (student number 609m5602) as from January 2014 doing a Master's degree in Science Education. I would be most grateful if you would allow me to conduct my research study in your school.

My topic of study is "an investigation into how Grade 10 Physical Sciences learners make sense of the concept of the resultant vector: A case study".

The insights generated from this study will be published in a thesis form and will become accessible to the decision makers in education, curriculum developers, teacher educators and Physics teachers in order to bring about improved achievements in Science. Should I get permission, I will first subject the learners to a diagnostic test, observe and videotape four lesson presentations, subject them to a summative test and interview them (learners).

I assure you that everything will be treated confidentially and you reserve the right to withdraw. You will be allowed to go through the draft thesis to ensure that the details are correct and I will not use your real name and that of the school.

Thanking you in advance

Yours Sincerely

Mr. TE Motsilili [073 1783 477]

Appendix C: The diagnostic test

PHYSICAL SCIENCE DIAGNOSTIC TEST GRADE 10

QUESTION 1

1.1. Define the term “force” /2/
1.2.Can forces be added together? Explain. /2/
1.3. When do we add forces? Explain /2/
1.4.When do we subtract forces? Explain /2/
1.5. Explain the terms: vector quantities and scalar quantities. /2/

[10]

QUESTION 2

2.1. Consider the forces acting below

2.1.1. What effect do F1 and F2 have if they act in the same direction? (More; Less OR Same) /2/

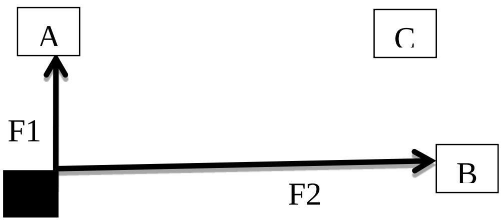
2.1.2. If the length of the force represents the size or the magnitude of the force, what is the effect of F1 and F3 acting the opposite direction? (More; Less OR Same) /2/

2.1.3. Assuming that F1 is equal to F2, what will their effect be if they act in the opposite direction? /3/

[07]

QUESTION 3

3.1. Consider the diagram below



3.1.1. Identify the position of the object after the forces F1 and F2 have acted on it. Choose from the positions given, A, B and C. /2/

3.1.2. Give reasons for your answer above. /2/

3.1.3. Describe F1 and F2 in terms of their orientation (Horizontal OR Vertical) /2/

3.1.4. Give an estimation of the angle between F1 and F2. /2/

[08]

TOTAL = 25 MARKS

Appendix D :Extract from CAPS for Grade 9 Natural Sciences

GRADE 9 TERM 3				
STRAND: ENERGY AND CHANGE				
TIME	TOPIC	CONTENT & CONCEPTS	SUGGESTED ACTIVITIES: INVESTIGATIONS, PRACTICAL WORK, AND DEMONSTRATIONS	EQUIPMENT AND RESOURCES
2 weeks	Forces	**Types of forces** • a force is a push or pull (or twist) exerted upon an object • force is measured in units called newtons (N)		• Textbooks and reference materials
		• forces that two objects exert on each other always act in pairs • a force can change the shape, direction and speed of an object • all forces acting on objects can be placed into two broad groups: - contact forces - field forces **Contact forces** • a contact force (including friction, tension, compression) results when two bodies are in contact (touch) with each other **Field forces (non-contact forces)** • field forces result from action-at-a-distance between two bodies • common examples of field forces include gravitational, magnetic and electrostatic forces	• **Investigating** physical (mechanical) push and pull forces on objects and materials, such as wooden blocks, sponges, erasers, fabric, balls and balloons. Observe what happens when one person pulls another, when both people pull, when one person pushes, when two people push	• Wooden blocks • Sponges • Rubber (eraser) • Fabric • Balls/balloons
		- **Gravitational force:** gravity is the force of attraction (pull) that objects/bodies have on one another due to their masses. For example the attraction of Sun and planets, Earth and Moon, Earth and objects on the surface (people and things) o objects with greater mass have more gravitational pull on each other o force decreases as distance between the objects increases *(refer to Grade 7 Planet Earth & Beyond)*	• **demonstrating** gravitational force using falling objects: direction is always "downwards" towards the centre of the Earth. The object (small mass) and the Earth (large mass) attract one another	
		o force of gravity is measured in newtons (N) o the weight of an object is the gravitational force exerted on it by the Earth (or the Moon, or another planet). It is also measured in newtons (N) ◊ the mass of the object stays the same no matter where it is determined ◊ however, the weight of an object will change when weighed in different places with different gravitational force such as on Earth compared to the Moon	• **measuring and recording** the weights (in newtons) of different objects using a spring balance and force meter	• Spring balances calibrated in newtons,

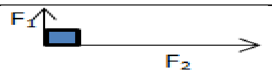
Appendix E: Transcriptions from the diagnostic test

Question and sub questions	Statement/ response	Learner – response
SQ 1.1.	-force is a pull or push	L1R – DSQ 1.1
	-Is the ability to do something to forces up or down	L2R – DSQ 1.1
	-Force is a push – pull	L3R – DSQ 1.1
	-It is to pull or push something	L4R – DSQ 1.1
	-Force something added in a vector to make the same velocity	L5R – DSQ 1.1
	-A force is a push or pull	L6R – DSQ 1.1
	-Force is a pull or push	L7R – DSQ 1.1
	-Force is a push or pull	L8R – DSQ 1.1
	-Force is a push or pull	L9R – DSQ 1.1
	-Force is a pull or push	L10R –D SQ 1.1
SQ 1.2	-Forces can be added when objects moves in one direction	L1R – DSQ 1.2
	-Yes, if you add together they will make a strong force	L2R – DSQ 1.2
	-Yes can be added together because you push something	L3R – DSQ 1.2
	-No, because there is no movement when we add forces together	L4R – DSQ 1.2
	-Yes, it is added together to find a solution of a pulling and pushing force	L5R – DSQ 1.2
	-Yes it can be added together to make velocity	L6R – DSQ 1.2
	-Yes if they are both negative	L7R – DSQ 1.2
	-Pull	L8R – DSQ 1.2
	-Yes forces can be added together	L9R – DSQ 1.2
	-Yes if they act in the same direction	L10R –D SQ 1.2
SQ 1.3	-When objects move in one direction	L1R – DSQ 1.3
	-Do something to add forces to be strong	L2R – DSQ 1.3
	-We add forces on the Newtons	L3R – DSQ 1.3

	-When we want a pull or push something to be done	L4R – DSQ 1.3.
	-When the forces need to be added together	L5R –D SQ 1.3
	-When it is in right hand side	L6R –D SQ 1.3
	-When they are facing in the same direction	L7R –D SQ 1.3
	-We add force for push	L8R –D SQ 1.3
	-When an object need more force we add force	L9R –D SQ 1.3
	-_	L10R – DSQ 1.3
SQ 1.4	-when two objects move in different directions or opposite direction	L1R – DSQ 1.4
	-If we subtract forces we want them not strong or take something easily	L2R – DSQ 1.4
	-We subtract forces on joules	L3R – DSQ 1.4
	-We subtract forces when we..	L4R – DSQ 1.4
	-We subtract forces when vectors are not the same	L5R – DSQ 1.4
	-When in a left hand side.	L6R – DSQ 1.4
	-When they are not facing in the same direction	L7R – DSQ 1.4
	-When we subtract forces is how will be the same	L8R – DSQ 1.4
	-When objects have less force, we subtract forces	L9R – DSQ 1.4
	-__	L10R –D SQ 1.4
SQ 1.5.	-Vector quantity is a physical quantity which has both magnitude and direction And scalar quantity is a physical quantity which has only magnitude	L1R –D SQ 1.5
	-Vector quantity is a physical quantity which has magnitude and direction And scalar quantity is a physical quantity which has magnitude only.	L2R – DSQ 1.5
	-Vector is a physical quantity have direction And scalar is a physical quantity have magnitude and direction	L3R – DSQ 1.5

	-Vectors are quantities that have same direction-scalars are quantities that have opposite direction	L4R – DSQ 1.5
	-Vector quantities are physical quantities have both magnitude and directions. And scalar quantities is a physical quantity that has magnitude only	L5R – DSQ 1.5
	-Scalar is a physical quantity that has magnitude only and no direction. And vector is a physical quantity which has magnitude direction	L6R – DSQ 1.5
	-Vector quantity is a physical quantity with both magnitude and direction. And scalar quantity is a physical quantity which has magnitude only	L7R – DSQ 1.5
	-Vector quantity is a physical quantity with both magnitude and direction. Scalar quantity is a physical quantity which has magnitude are size only	L8R – DSQ 1.5
	-Physical quantity with both magnitude and direction. And physical quantity with only magnitude	L9R – DSQ 1.5
	-Vector quantity is quantities that magnitude of a vector. Scalar quantity is quantity that opposite direction	L10R – DSQ 1.5
SQ 2.1	-More	L1R – DSQ 2.1
	-Same	L2R – DSQ 2.1
	-More	L3R – DSQ 2.1
	-More	L4R – DSQ 2.1
	-Same	L5R – DSQ 2.1
	-Positive effect the act in the same direction	L6R – DSQ 2.1
	-More	L7R – DSQ 2.1
	-More	L8R – DSQ 2.1
	-More	L9R – DSQ 2.1
	-More	L10R – DSQ 2.1
SQ 2.2	-less	L1R – DSQ 2.2
	-F_1 has less and F_3 have more	L2R – DSQ 2.2
	-less	L3R – DSQ 2.2

	-less	L4R – DSQ 2.2
	-less	L5R – DSQ 2.2
	-Neutral effect mare	L6R – DSQ 2.2
	-less	L7R – DSQ 2.2
	-less	L8R – DSQ 2.2
	-Same	L9R – DSQ 2.2
	-less	L10R – DSQ 2.2
SQ 2.3	-Will be equal to zero	L1R – DSQ 2.3
	-F_1 & F_2 they act in the same direction and they are having negative signs	L2R – DSQ 2.3
	-They get more direction	L3R – DSQ 2.3
	-They will be in less	L4R – DSQ 2.3
	-It will be the same	L5R – DSQ 2.3
	-It is positive effect because are added in the right hand side	L6R – DSQ 2.3
	-less	L7R – DSQ 2.3
	-they act in the opposite direction in going to be negative	L8R – DSQ 2.3
	-They will subtract each other and force will be less	L9R – DSQ 2.3
	-_	L10R – DSQ 2.3
SQ 3.1	-Position A	L1R – DSQ 3.1
	-A is F_1 and B is F_2	L2R – DSQ 3.1
	-Point C	L3R – DSQ 3.1
	-A and B have acted on it	L4R – DSQ 3.1
	-C	L5R – DSQ 3.1
	-$F_3^2 = F_1^2 + F_2^2 = 1^2 + 2^2 = 1 + 4 =$ C= 5	L6R – DSQ 3.1
	-C	L7R – DSQ 3.1
	-We can add force F_3	L8R – DSQ 3.1
	-C	L9R – DSQ 3.1
	-A	L10R – DSQ 3.1
SQ 3.2	-Because it has largest force	L1R – DSQ 3.2
	-Arrows point from the force to letters	L2R – DSQ 3.2
	-They do not have direction	L3R – DSQ 3.2
	-They are opposite in direction	L4R – DSQ 3.2
	-They are positioned to one another	L5R – DSQ 3.2
	-S<S	L6R – DSQ 3.2
	-It is a resultant	L7R – DSQ 3.2
	-Because F_3 is negative	L8R – DSQ 3.2

	-It is where they will be added or combined	L9R – DSQ 3.2
	-F_1 and F_2 in terms of their orientation	L10R – DSQ 3.2
SQ 3.3.	-F_1 is vertical and F_2 is horizontal	L1R – DSQ 3.3
	-F_1 is horizontal and F_2 is vertical	L2R –D SQ 3.3
	-F_1 is horizontal and F_2 is vertical	L3R – DSQ 3.3
	-F_1 is vertical and F_2 is horizontal	L4R – DSQ 3.3
	-Vertical	L5R – DSQ 3.3
	-Horizontal	L6R – DSQ 3.3
	-Horizontal	L7R – DSQ 3.3
	-F_1 is vertical and F_2 is horizontal	L8R – DSQ 3.3
	-Vertical	L9R – DSQ 3.3
		L10R – DSQ 3.3
SQ 3.4	-90^0	L1R – DSQ 3.4
	-90^0	L2R –D SQ 3.4
	-It is angle D	L3R – DSQ 3.4
	-They act in opposite direction	L4R – DSQ 3.4
	-They are vertical on a straight line angles	L5R – DSQ 3.4
	-Square	L6R – DSQ 3.4
	-90^0	L7R – DSQ 3.4
	-The estimation of the angle between F_1 and F_2 is a right angle	L8R – DSQ 3.4
	-it is 90^0	L9R – DSQ 3.4
	-the position of the object after F_1 and F_2 and have acted on it.	L10R –D SQ 3.4

Appendix F: Extract from CAPS for grade 7 Mathematics

CONTENT AREA	TOPICS	CONCEPTS AND SKILLS	SOME CLARIFICATION NOTES OR TEACHING GUIDELINES	DURATION (in hours)
Measurement	4.2 Surface area and volume of 3D objects	**Surface area and volume** • Use appropriate formulae to calculate the surface area, volume and capacity of: - cubes - rectangular prisms • Describe the interrelationship between surface area and volume of the objects mentioned above **Calculations and solving problems** • Solve problems involving surface area, volume and capacity • Use and convert between appropriate SI units, including: - $mm^2 \leftrightarrow cm^2$ - $cm^2 \leftrightarrow m^2$ - $mm^3 \leftrightarrow cm^3$ - $cm^3 \leftrightarrow m^3$ • Use equivalence between units when solving problems: - $1 cm^3 \leftrightarrow 1\ ml$ - $1\ m^3 \leftrightarrow 1\ kl$	**What is different to Grade 6?** • In Grade 6 learners did not have to use formulae to calculate surface area and volume. • **Formulae learners should know and use:** - the volume of a prism = the area of the base x the height - the surface area of a prism = the sum of the area of all its faces - the volume of a cube = l^3 - the volume of a rectangular prism = $l \times b \times h$ • **For conversions, note:** - if 1 cm = 10 cm then 1 cm^3 = 1 000 mm^3 and - if 1 m = 10 cm then 1 m^3 = 1 000 000 mm^3 or 1 000 000 or $10^6 cm^3$. - an object with a volume of 1 cm^3 will displace exactly 1 ml of water, and - an object with a volume of 1 m^3 will displace exactly 1 kl of water. • Emphasize that the amount of space inside a prism is called its capacity; and the amount of space occupied by a prism is called its volume. • Investigate the nets of cubes and rectangular prisms in order to deduce formulae for calculating their surface areas.	8 hours
REVISION/ASSESSMENT: At this stage learners should be assessed on: • calculating and solving problems with common fractions and decimal fractions • using formulae to find area and perimeter of 2D shapes • using formulae to find volume and surface area of 3D objects				9 hours

Appendix G: Physical Sciences summative test Grade 10

Time: 1 hour

Question 1 [multiple choice]

Choose the correct answer from the ones given in options:

1.1. A truck travelling West collided with a small car and pushed it to the West for 15 seconds over distance of 20 meters.
   A. Acceleration
   B. Distance
   C. velocity
   D. Time

1.2. It is an example of a vector quantity
   A. Distance
   B. Time
   C. Force
   D. Energy

1.3. Physical quantities that have both magnitude and direction
   A. Scalars
   B. Forces
   C. Vectors
   D. Velocities

1.4. It is a physical quantity
   A. Electric field strength
   B. Momentum
   C. Work
   D. Weight

1.5. A car travels for 23 km in 60 minutes. It speed is…
   A. 3,8 km/m
   B. 23 km/s
   C. 23 km/h
   D. 2,60 km/h

[5X2= 10]

Question 2

Define the following scientific terms

2.1. Resultant vector

2.2. Vector quantity

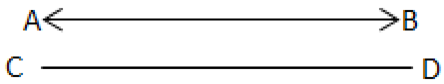
2.3. Displacement

2.4. Scalar quantity

2.5. Energy

5 X 2= 10

Question 3

3.1. 

Describe the difference between the two lines AB and CD in terms of vectors and scalars. /2/

3.2. When do we say the vectors are equal? /2/

3.3. Can vectors acting in opposite direction be equal? Explain. /2/

3.4. Mmoelo is applying a force of 768 N on the wall, but the wall does not move or shake. What is the resultant force in this action? Explain your answer. /2/

3.5. There are two methods of determining the resultant vector graphically, (1) Tail – to – head method and (2) Parallelogram method. Describe the two methods fully. /4/

[12]

Question 4

4.1. The two forces F_1 and F_2 act from the same point. F_1 is 20N to the West and F_2 is 50N to the South. Use a scale of 10 mm: 5 N to draw the graph of these forces. /3/

4.2. Which theorem would you use to calculate the resultant of these two forces? /1/

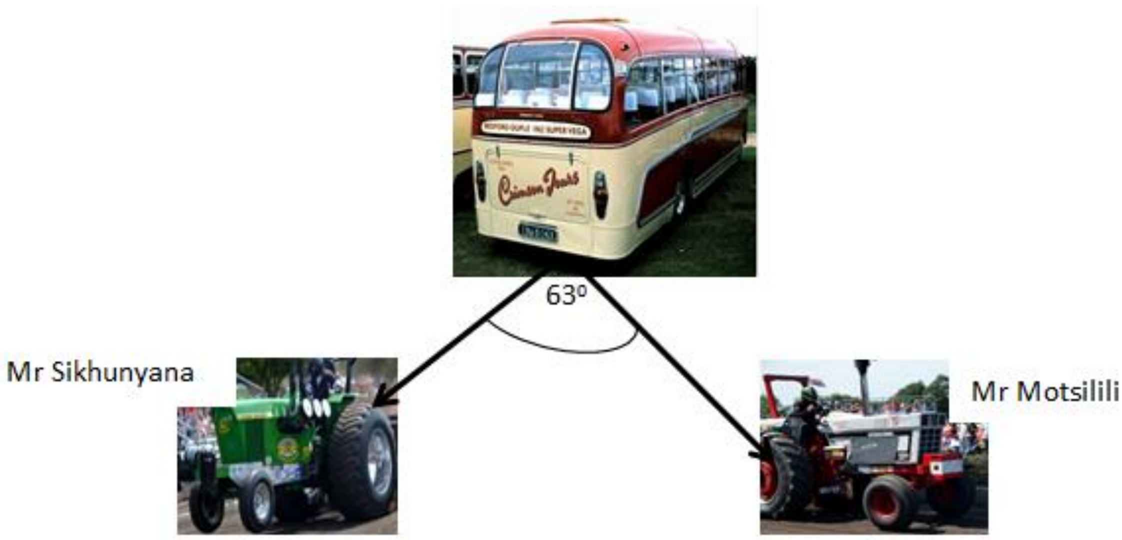
4.3. Use the theorem you mention above in 4.2, to calculate the resultant of these two forces. /4/

4.4. If the resultant force is making an angle of θ with the F_1, calculate angle θ. /3/

[11]

Question 5

4. The two tractors are pulling a bus stuck in the mud. The first tractor is using a force of 1200N and the second tractor is pulling with the force of 800N. The angle between their chains is 63^0.



Use tail-to-head method to determine the resultant force of the two tractors.

[Scale of 10mm : 200N] /4/

5. The two men are pulling a tree in one direction while the third one is chopping it down. The ropes make an angle of 37^0. The first man pulls with a force of 480N and the second one is pulling with a force of 320N. Use a scale of 1cm: 40N and a parallelogram method to determine the resultant force of two forces. /5/

[11]

[Total = 50 marks]

Appendix H: Physical Sciences summative test Grade 10

MEMORANDUM

QUESTION 1

1.1. C √ √
1.2. C √ √
1.3. C √√
1.4. C √√
1.5. C √√

QUESTION 2

5.1. Resultant vector is a single vector which has the same effect as the original vectors combined. √√
5.2.Vector quantity is a physical quantity which has both magnitude and direction.√√
5.3. Displacement is a shortest distance from the starting point to the final point. √√
5.4.Scalar quantity is the physical quantity which has magnitude ONLY and n direction.√√
5.5. Energy is the rate/ ability to do work. √√

QUESTION 3

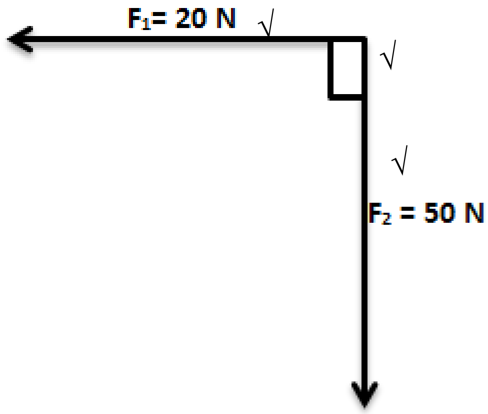
3.1. Line AB is a vector because it has direction indicated by arrows.
Line CD is a line segment and a scalar because there is no indication of direction by any arrow. √√
3.2. Vectors are equal only if they have the same magnitude and direction.√√
3.3. Yes, the difference will be their signs and direction. √√
3.4. The resultant force is zero, because Mmoelo's force has no effect on the wall.√√

3.5. (1) Tail-to-head method is when the tail of a resultant vector is from the tail of the first vector to the head of the last vector. √√

(2) Parallelogram method is when the two vectors acting at an angle are extended to complete a parallelogram. Then the diagonal of the parallelogram becomes the resultant of the vectors.√√

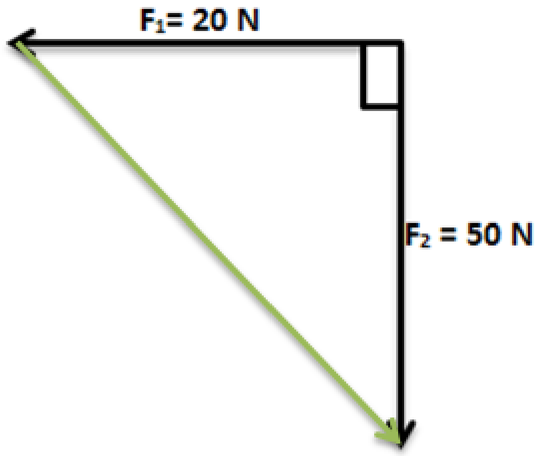
QUESTION 4

4.1.



4.2. The theorem of Pythagoras. √

4.3.



$(F_{res})^2 = (F_1)^2 + (F_2)^2$ √

$= 20^2 + 50^2$

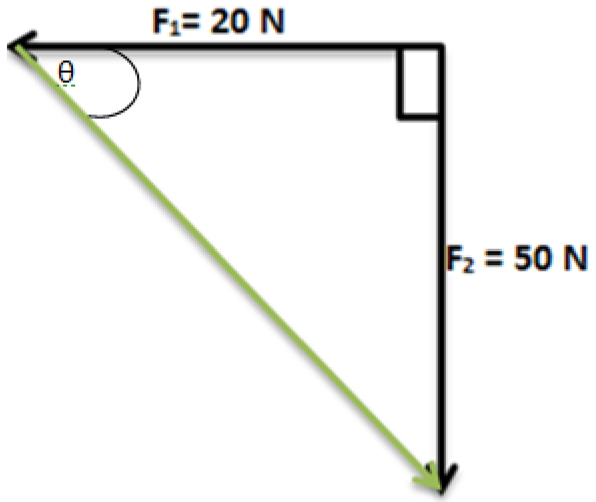
$= 400 + 25\ 00$

$= 2900$ √

$F_{res} = \sqrt{2900}$ √

$= 53.85$ N √

4.4



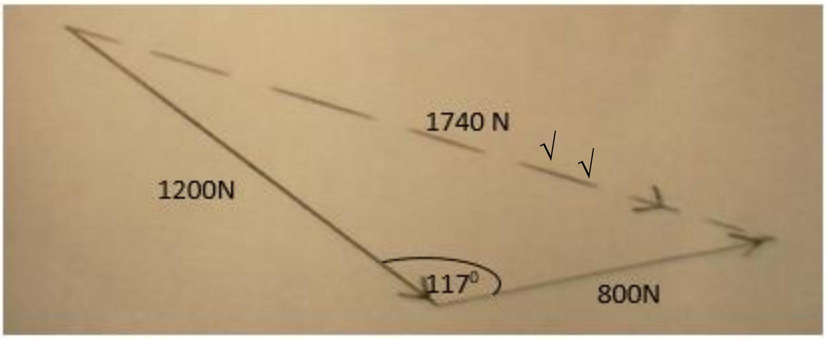
$Tan\theta = \frac{50}{20}$ √

$= 2,5$

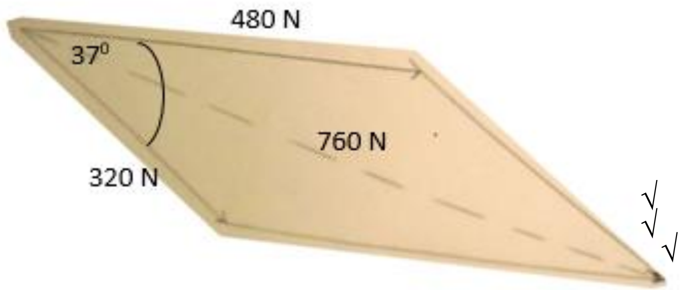
$\theta = Tan^{-1}(2,5)$ √

$\theta = 68,20^0$ √

QUESTION 5



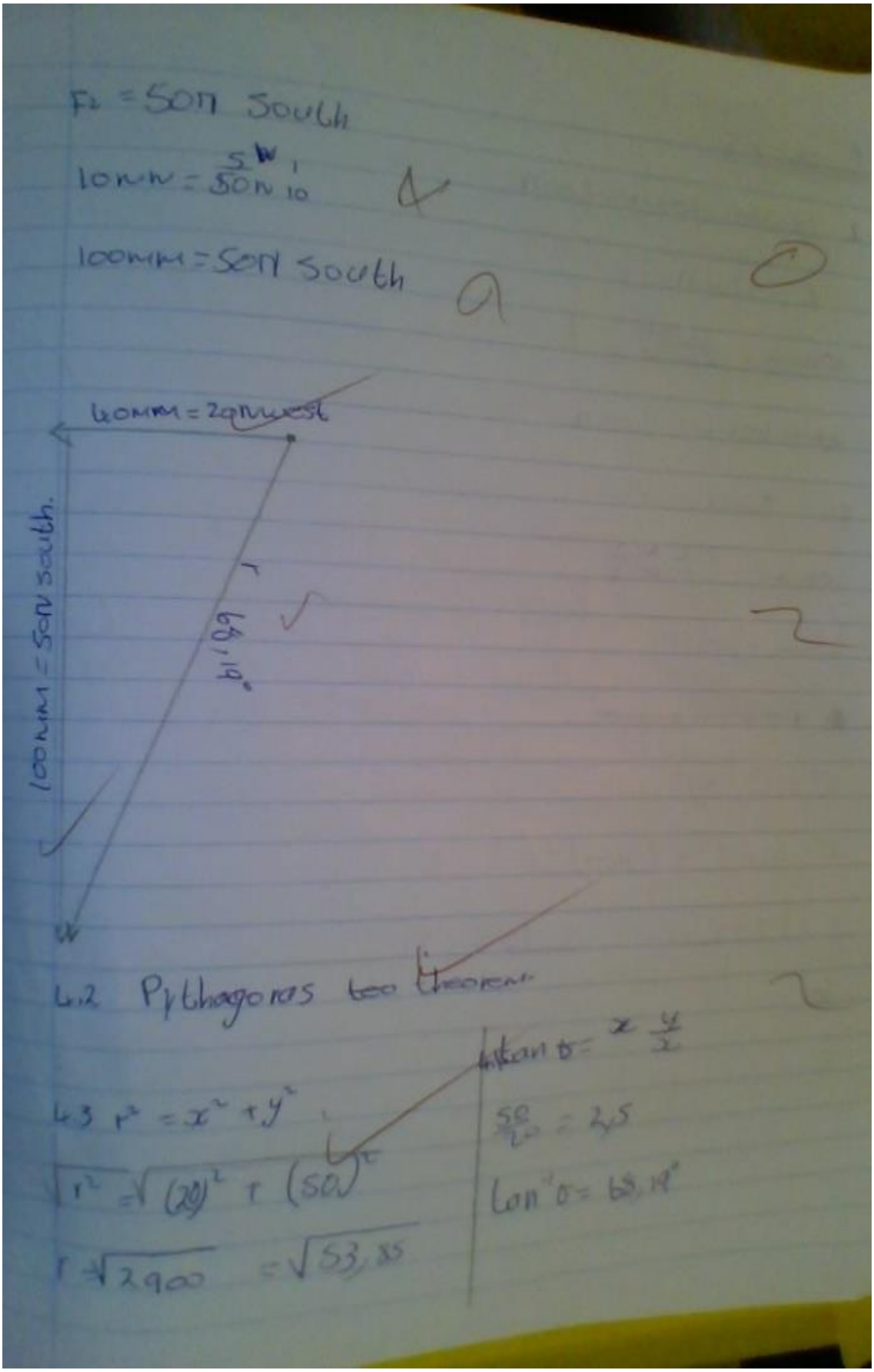
1. The resultant vector is between {1718 N and 1740 N} √
2. The parallelogram is drawn below



√ √ √

The resultant force calculated as {760 N and 760, 36 N} √ √

Appendix H: Learners' conversion of units



Appendix I. INTERVIEW SCHEDULE

Questions

1. How did you understand the lesson on vectors as compared to other topics or lessons?
2. Which part was more interesting? And which part was not interesting?
3. Was there any link between Physics and Mathematics? What was it?
4. Was it the first time you learnt about vectors? If not, where and when did you learn about it?
5. Was it the first time you learnt about force? If not, where and when did you learn about it?
6. Would you like the teacher to repeat the lesson and why?

Appendix J: Learner 2 script

12/25

LEARNER 2

Physical sciences

Question 1

1.1 Force : is the ability of do some thing to forced down or up.

1.2 Yes becouse if you add together they will make strong force.

1.3 We will do something to add force to be strong like : make good addings and do something to make force take place.

1.4 If we subtruct forces we was want to made forces be not strong or take something easily.

1.5 Vector quantity : is the physical ~~Magnitude~~ quantity that have both magnitude and direction.

Scalar quantity : is the physical quantity that have magnitude (size) only.

HIDING THE SCHOOL STAMP

Question 2

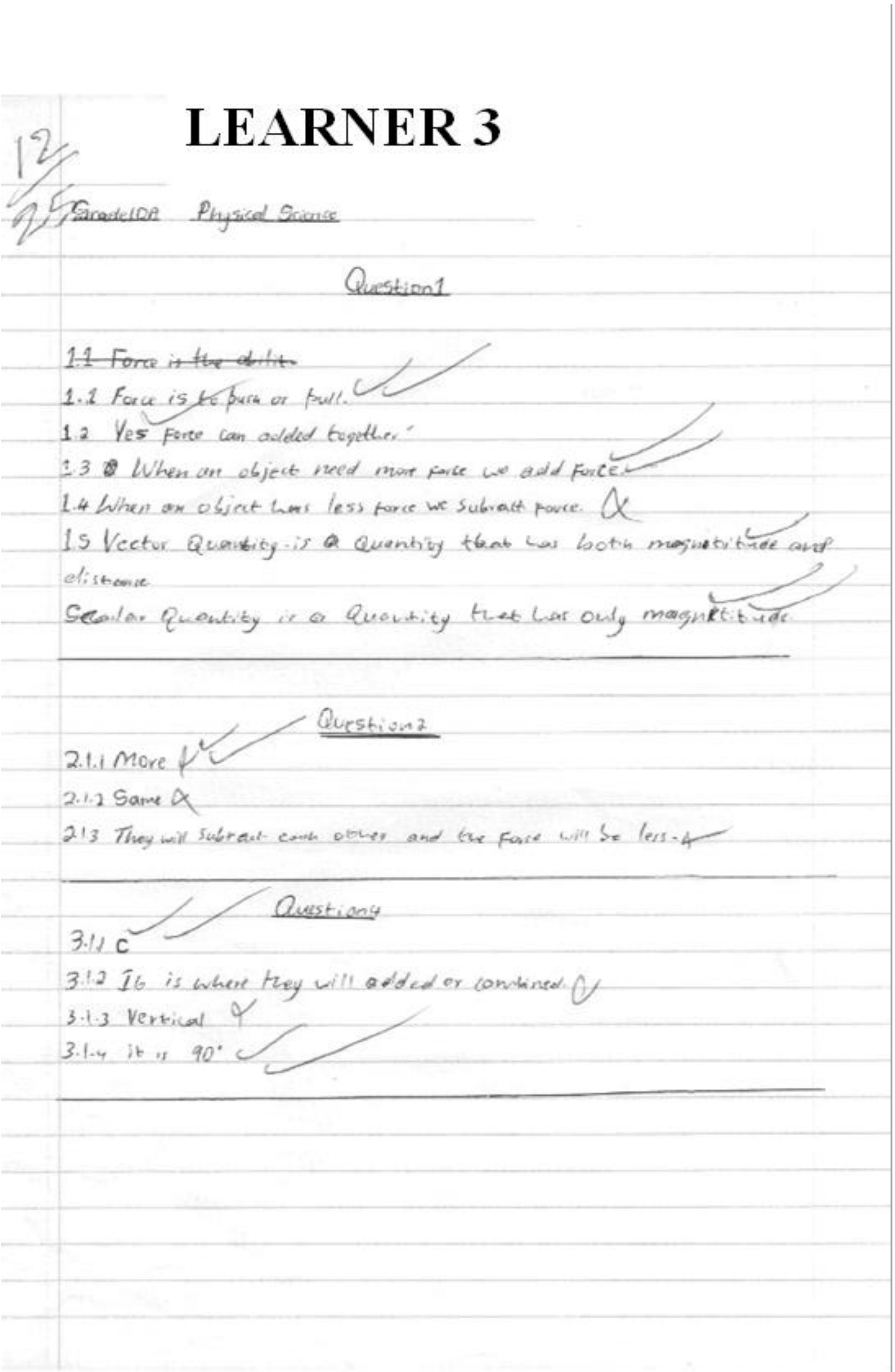
2.1

2.1.1 F_1 and F_2 they are same and they are less.

2.1.2 F_1 it have less. and F_3 it have more.

2.1.3 F_1 and F_2 they act in same direction and they are have negative sign.

Appendix K: Learner 3 script



LEARNER 3

12/25

Grade10A Physical Science

Question1

~~1.1 Force is the abilit~~

1.1 Force is to push or pull.

1.2 Yes force can added together.

1.3 When an object need more force we add force.

1.4 When an object has less force we subtract force.

1.5 Vector Quantity is a Quantity that has both magnitude and distance

Scalar Quantity is a Quantity that has only magnitude

Question2

2.1.1 More

2.1.2 Same

2.1.3 They will subtract each other and the force will be less.

Question4

3.1.1 C

3.1.2 It is where they will added or combined.

3.1.3 Vertical

3.1.4 it is 90°