

Challenges and prospects of teaching the Doppler Effect at grade 12

By

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DECLARATION

I declare that **Challenges and prospects of teaching the Doppler Effect at grade 12** is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

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SIGNATURE

(SURE MUPEZENI)

.....

DATE

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- The Subject Advisors, Principals, Physical Science Teachers of the schools where the research was conducted.
- All the learners who have participated in this study.

ABSTRACT

This study focuses on challenges and prospects of the teaching of the Doppler Effect to grade 12 learners. The challenges of teaching the Doppler Effect were established and these findings influenced the development of activities. These activities were tested, refined and re-tested in an iterative cycle and finally provided prospects on teaching the Doppler Effect. Educational Design Research (EDR) was used to bridge theory and practice in education.

This study was done in the Vhembe district in the Limpopo province. In the first cycle, questionnaires and interviews with 32 teachers and a subject advisor were used to establish the baseline with regards to the challenges of teaching the Doppler Effect. After the analysis of the data which forms the first cycle of EDR, the content and methodological problems faced by teachers when teaching the Doppler Effect were revealed.

In the second cycle of the EDR, learning activities were developed that was informed by the analysis and tried out in 2 schools by learners and their teachers. Completed activity sheets were marked and the results were used to determine if there were a correlation between the activity sheets and the written test. Problems were documented and changes to the activities were again made and tried out in 10 schools by 216 learners with the help of 10 teachers. The data collected from the learners' work sheets were analysed. Pearson's product moment correlation has shown that there is a statistically significant relationship ($r = 0.65$; $p < 0.01$) that exists between these design-research activities and solving of problems on the Doppler Effect.

An instructional manual was developed comprising of the final activities. This was distributed amongst the district officials and teachers to assist them in the teaching of the Doppler Effect in the Vhembe district.

Key terms

Grade 12-curriculum, educational design research activities, physics, Doppler Effect, teaching-approaches

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LIST OF ABBREVIATIONS

ACE	-	Advanced Certificate in Education
ASEI	-	Activity, Student, Experiment, Improvisation
CAPS	-	Curriculum and Assessment Policy Statement
DOE	-	Department of Education
EDR	-	Education Design Research
FET	-	Further Education and Training (i.e. grade 9, 10 & 12)
LO	-	Learning Outcome
MLA	-	Mastery Learning Approach
NCS	-	National Curriculum Statement
OBE	-	Outcomes-based Education
PDSI	-	Plan, Do, See, Improve
RNCS	-	Revised National Curriculum Statement
RSA	-	Republic of South Africa
SET	-	Science, Engineering and Technology
SPSS	-	Statistical Package for Social Sciences
UNESCO	-	The United Nations, Scientific and Cultural Organisation
UNISA	-	University of South Africa

CHAPTER 1: INTRODUCTION AND BACKGROUND

1.1 Introduction

Applications of the Doppler Effect are apparent in everyday life. The distinct change in the sound of a siren of an ambulance or fire truck is heard; while the ambulance approaches the pitch of the siren is relatively high but as the ambulance passes and moves away the pitch suddenly drops. The Doppler Effect is used in speed traps to measure the velocity of detected vehicles by traffic officers. It is also applied in medicine. An echocardiogram produce an assessment of the direction of blood flow and the velocity of blood and cardiac tissue at any point in a human body using the Doppler Effect. The measurement of blood flow rate in veins and arteries based on the Doppler Effect is used for diagnosis of vascular problems like stenosis. In astronomy, the Doppler Effect for light has helped scientists in realising that the universe is expanding.

The Doppler Effect is one of the topics in the grade 12 physical science curriculum (Department of Education, 2003, p 41). The physical science curriculum does not only indicate what content has to be taught but describes knowledge, skills and values that learners should acquire by the end of the Further Education and Training band (FET) by means of Learning Outcomes (LO). The three learning outcomes are stated below (Department of Education, 2003, pp 13-14).

LO1 The learner is able to use process skills, critical thinking, scientific reasoning and strategies to investigate and solve problems in a variety of scientific, technological, environmental and everyday contexts.

LO2 The learner is able to state, explain, interpret and evaluate scientific and technological knowledge and can apply it in everyday contexts.

LO3 The learner is able to identify and critically evaluate scientific knowledge claims and the impact of this knowledge on the quality of socio-economic, environmental and human development.

The topic Doppler Effect is also included in the new curriculum, the Curriculum and Assessment Policy Statement (CAPS), (Department of Education (DOE), 2010) that will be implemented for the first time in 2012 starting with Grade 10. The CAPS was developed for each subject to replace Subject Statements, Learning Programme Guidelines and Subject Assessment Guidelines in Grades R - 12. The general aims of the South African Curriculum are explained in the National Curriculum Statement (NCS) Grades R-12 which includes the three LOs.

Teachers faced challenges in teaching the Doppler Effect (Flick, 1993; Makgato & Mjii, 2006). The main challenges faced by teachers were lack of content knowledge on the topic, inadequate text books and science equipment (Department of Education, 2008). In order to address these challenges, activities were developed for use when teaching the topic, making use of demonstrations with locally available materials.

1.2 Background to the study

The challenges faced by teachers have had an effect in the performance of learners in their final examinations. The final marks for grade 12 comprises of 75% examination mark and 25% tests and practical investigations (Department of Education, 2003). The performance of learners in physical science at grade 12 in South Africa has been poor. The study was carried out in Limpopo province because the researcher is working in a secondary school in this province and it was easier to carry out the research. Table 1 show the percentages indicating learners in South Africa who achieved marks of 30% and above, 30% is being considered because it is a pass mark for mathematics and physical science in South Africa (Department of Education, 2011).

Table 1: Learners' performance in South Africa for the years 2008, 2009 and 2010

	Year		
Subject	2008	2009	2010
Physical	54.9%	36.8%	47.8%

science			
Mathematics	45.7%	46.0%	47.4%

Table 2 indicates the percentage of learners in the Limpopo province where this study was carried out (again percentages are indicating learners who achieved marks of 30% and above) in physical science (Department of Education, 2011).

Table 2: Learners' performance in Limpopo Province for the years 2009 and 2010

Subject	Year	
	2009	2010
Physical science	31.8%	16.1%
Mathematics	39.2%	39.6%

Table 3: Learners' performance in Vhembe district for the years 2009 and 2010

Subject	Year	
	2009	2010
Physical science	40.6%	52.8%
Mathematics	46.7%	44.0%

The above information has clearly shown that in physical science learners have underperformed nationally and worse in the Limpopo province. The learners' performance in mathematics is also not good; however they have done better compared to what they did in physical science. The possible reason for the improvement in physical science in 2010 in Vhembe district (Table 3) compared to the decline for mathematics is, unlike in mathematics; physical science learners in

the district were given common tests throughout the year, and these tests were covering all the learning outcomes of the subject, as a result learners had appropriate practice before they wrote their final examinations.

In Limpopo, the 2009 mathematics matric examination results were better than the results for physical science by 7.4% and in 2010 physical science were outperformed by 23.5% (Table 2).

1.3 Rationale of the study

Two factors contributed towards the motivation of this study.

Firstly, there are no published research studies on the teaching and learning of the Doppler Effect in grade 12 in Vhembe district of Limpopo province. Secondly, the topic offers learners scientific reasoning and strategies to investigate and solve problems learners encounter in everyday contexts. This poses a challenge in the understanding of the Doppler Effect (Flick, 1993) by learners since some teachers do not use experiments or demonstrations when teaching physical science (Rapudi, 2004).

1.3.1 How the study fills the gap

The South African government stipulates policy on curriculum and assessment in the schooling sector by means of its National Curriculum Statement Grades R-12 (NCS). The NCS learning outcomes (paragraph 1.1) outlines that the learner should be able to explain, interpret, evaluate scientific and the technological knowledge and apply it in everyday experiences. On daily basis learners are encountering the Doppler Effect phenomenon but some might not be aware of it. This study attempts to show that science is not detached from our daily life; we use science and apply scientific methods daily at times not knowing it.

The first LO is addressed when learners performed the activities during the lesson and applied and constructed knowledge. The second LO is achieved when the learners stated, explained and interpreted the phenomena of the Doppler Effect. The third LO was addressed when the learners did the activity using a bicycle and a cell phone; this helped them to understand how science relates to their everyday lives. In addition, the learners need to critically evaluate the impact of scientific knowledge on the environment and human development to link the theory and practice. Therefore,

the Doppler Effect topic could provide the learner the opportunity to address all three learning outcomes.

1.4 Aim of the study

The aim of this study was to investigate the challenges of teaching the Doppler Effect to grade 12 learners in Vhembe district. In order to address these challenges, activities were developed and tried out in classrooms, laboratories and outdoors.

The main thrust of the study was to investigate the challenges and the prospects of teaching the Doppler Effect at grade 12. This was achieved by:

1. Establishing a baseline to identify the challenges that the teachers have when teaching the topic Doppler Effect to grade 12 learners.
2. Developing and evaluating activities to teach the Doppler Effect to grade 12 learners in different schools in the Vhembe district.

1.5 Research Questions

This study was guided by the need to identify and possibly address the challenges that the teachers have when teaching the topic Doppler Effect to grade 12 learners. Therefore the research questions are phrased as:

1. Which aspects of the topic Doppler Effect do the teachers find challenging?
 - a. What are the challenges identified by the teachers in terms of content knowledge when teaching the Doppler Effect to grade 12 learners?
 - b. What are the challenges identified by the teachers in terms of teaching approaches when teaching the Doppler Effect to grade 12 learners?
2. What is the effectiveness of teaching the Doppler Effect using developed learner-centred activities?

1.6 Significance of the study

The objective of physical science (grade 10-12) is to advance knowledge and skills in scientific inquiry and problem solving during written tests, to construct and apply scientific and technological knowledge and understand the nature of science and its relationship to technology, society and the environment (Department of Education, 2010). Using Educational Design Research (EDR) this study investigated the development and evaluation of activities that enable learners to predict, interpret and explain their observations. The learners were able to manipulate equipment making

decisions using critical and creative thinking. Learners were encouraged to use science equipment effectively showing responsibility towards the environment and the well being of other learners by being resourceful and collaborative. The developed activities could have implications for the effective preparation and continuous support of teachers. Substantial information on the Doppler Effect is provided in the instructional manual to improve on the teacher effectiveness by increasing teacher content knowledge and suggesting an alternative teaching method. The new suggestion in the CAPS document is that teachers have to do one practical activity per term, and this could be a practical guideline on how to carry out the practicum related to the Doppler Effect.

1.7 Limitations of study

Due to the possibility of respondents to answer dishonestly, results might not accurately reflect the opinions of all members of the chosen sample. The sample was small because it was chosen from one district only and the schools` proximity to each other reduced transport costs during the distribution and collection of questionnaires and so generalisation is not justifiable. This kind of study has been done only in the Vhembe district of the Limpopo province. The 10 schools were purposefully chosen for the study and the sample was too small to justify general conclusions. These limitations show the limited nature of the research as reported in this study but this should not be construed as a weakness in the research design.

1.8 Delimitation

People do not want to answer many written long questions, so to ensure maximum return of survey instruments and manageability of collected data, the instruments used were mostly multiple-choice items and a few open-ended response items. The English language used in the activity sheets for learners was simple and straight forward without double meaning making it easy for learners to understand, as indicated in the pilot stage. There were a large number of potential participants in the study population; however the study did focus on members located within Thohoyandou cluster of schools, in Thohoyandou, Limpopo province, South Africa, and purposeful samples of 32 teachers and 10 schools were chosen. Thohoyandou cluster of schools falls under the Vhembe district.

1.9 Assumptions

It was assumed that the teachers and the subject advisor answered all questions honestly and to the best of their abilities. Since the teachers were trained on how to carry-out the activities earlier, it is assumed that the test papers and activity sheets were not leaked.

1.10 Operational definition of terms

The following operational definitions are applicable to the study:

The Doppler Effect: Suppose a learner stands beside a road while an ambulance passes by at high speed sounding its siren. As the ambulance approaches, it produces a sound with high frequency, and when it passes by, the frequency heard drops significantly. The frequency of the sound heard by the learner is much higher while the ambulance was approaching, than while it was moving away. This phenomenon is called the Doppler Effect.

Educational design research activities: These are developed practical activities which have the aim of solving a practical problem and to advance our knowledge, the designed product is refined until an acceptable product is made which can be adopted elsewhere (Barab & Squire, 2004).

Professional development: The individual teacher is responsible for his/her lifelong career advancement and this includes “those processes that improve the job-related knowledge, skills, or attitudes of school employees” (Sparks & Loucks-Horsley (1990) as cited by Kriek, 2005).

Teaching approach: Teaching approaches refer to teaching strategies, ways of conducting instructional activities and techniques that are used by teachers to achieve their teaching objectives.

Curriculum: This refers to the plan for learning which focuses on rationale, aims, objectives and content, striving to enable all learners to reach their maximum learning potential by setting the learning outcomes to be achieved by the end of the educational process (Department of Education, 2003).

1.11 Organisation of the study

- i. Chapter one presents the introduction, background rational and aim of the study. The research questions are presented as well as the significance of the study, limitations and delimitations of the study.
- ii. Chapter two gives a summary of the review of related literature and presents other research related to challenges and prospects of teaching physical science as well as the theoretical framework.
- iii. Chapter three focuses on the research design, the study population, instruments, the validity and reliability of the instruments, the methodology, data collection, and ethical considerations.
- iv. The collected data, data analysis and the findings are presented in chapter four.
- v. Chapter five provides the summary of the study, conclusions, discussions, recommendations and concluding remarks.

1.12 Summary

The study`s orientation was established in this chapter. The background, the rationale, aim of the study and the research questions were presented. In addition, the significance of the study was discussed.

CHAPTER 2: REVIEW OF RELATED LITERATURE

2.1 Introduction

This chapter provides a review of literature related to the challenges and prospects in teaching Physics at Secondary School level, and the teaching of the Doppler Effect in particular. This study was carried out with the purpose of filling a gap, by means of designing an instructional manual for grade 12 learners on the Doppler Effect comprising of activities addressing all three learning outcomes simultaneously as stated in the FET physical science curriculum.

2.2 Challenges faced by teachers

Physics is a conceptually demanding subject and teachers need to improve their learners' scientific language so that they may be able to communicate and learn science (Angell, Guttersrud, Henriksen, & Isnes, 2004; Lemke, 1990; Osborne, 1996). Teachers face challenges in teaching the Doppler Effect (Flick, 1993) and this could be because it is an abstract science concept. Other challenges faced by teachers when teaching have been itemised such as curriculum implementation, professional development, content knowledge, teaching approach, and school environment (Grossman, 1990; Kriek & Basson, 2008; Kriek & Grayson, 2009; Shulman, 1987).

2.2.1 Curriculum implementation

Educational authorities in South Africa have been occupied with reforming the national curriculum for schools (Department of Education, 1997) since the mid nineties. The background to the changes that took place in the education system over the past few years was enlightened by (Lombard & Grosser, 2008):

“Recent reforms of the South African educational system which were characterized by the ideals that the country needs to produce independent, critical thinkers who are able to question, weigh evidence, make informed judgments and accept the incomplete nature of knowledge (Republic of South Africa (RSA), 1995, p 22). As a result, an OBE curriculum was introduced in

schools from 1998 — initially by means of Curriculum 2005 (C2005), which was followed by the Revised National Curriculum Statement (RNCS) and by the National Curriculum Statement (NCS)” p 28.

Since then there has been some changes; outcomes-based education (OBE) which forms the foundation for the curriculum in South Africa has been introduced. The OBE as a way of teaching encourages learner-centred and activity based approach to education (Department of Education, 2003). In addition, the NCS prescribes the Learning Outcomes for the physical sciences and these are to ensure continuity by linking directly with the General Education and Training (GET) Learning Outcomes. . New topics such as the Doppler Effect were introduced in the NCS. As a result of these changes some of the teachers find it difficult to adjust to the NCS curriculum.

The National Senior Certificate (NCS) was introduced in 2008 for the first time and this resulted that, 2010 was the third consecutive year in which grade 12 learners were assessed by means of this examination. Only in 2014 will Grade 12 learners be examined under CAPS (see paragraph 1.1). It is essential that government continue to support innovative methods of teaching science and provide the teacher professional development necessary to transform their practices (Osborne & Dillon, 2008, p 22).

2.2.2 Professional development

Professional development occurs when teachers aim for continuous improvement in their professional skills and content knowledge after the initial training that was required for them to be employed. Professional development is important because improving teacher knowledge and teaching skills raises learners` performance (Sparks & Hirsh, 2000). In addition, “If quality education is envisaged for all learners in South Africa, ongoing professional development is essential” (Kriek, 2005, p 17). A subject-based professional development activity is more effective in empowering the teacher with the content knowledge and skills (Soulsby & Swain, 2003). However, a study by MacBeath and Galton (2004) found that teachers were not given enough opportunities for subject-based professional development. Scientific discoveries are made yearly and textbooks are edited to include the new discoveries.

As scientific world is dynamic; a teacher should always be researching and learning new ideas and discoveries (Farrow, 1999; King, 2002). A teacher should be involved in personal studies in order to improve on skills and knowledge (Smith & Lovat, 1995). The teacher,

“will achieve ongoing personal, academic, occupational and professional growth, through pursuing reflective study and research in his/her learning area, in broader professional and educational matters, and in other related fields” (Killen, 2007, p 367).

Teachers who give themselves time to study and research could enhance their content knowledge and they might gain confidence which is essential in qualifying the teachers` competitiveness (Schmidt & Cogan, 1986). For a teacher to gain new knowledge, the teacher must be open minded, creative, innovative and “posing significant, contextualised, real-world situations, and providing resources, guidance, and instruction to learners as they develop content knowledge and problem-solving skills” (Mayo, Donnelly, Nash & Schwartz, 1993, p 227).

Teacher professional development programs are necessary because enhanced learner performance correlate with teachers continued learning activities (Brown, Smith, & Stein, 1995; Wiley & Yoon, 1995). Furthermore, according to Mayer, Mullens, & Moore, (2001) effective teaching is achieved by quality professional development involvement by the teachers.

2.2.3 Content knowledge

Wright and Wright (2000) have stated that a teacher cannot teach what she/he does not understand or accept. In this study, content knowledge was considered because teachers` content knowledge of the Doppler Effect contributes to the learners` understanding of the topic. An effective teacher should have appropriate teaching skills and relevant qualifications (Joyce & Showers, 1988; Fullan, 1991).

Studies suggest that higher levels of student achievement are associated with more qualified and experienced teachers (Grayson, 1996). However, in South Africa the poor training of teachers has been highlighted by the report of the Task Team for the Review of the Implementation of the National Curriculum Statement (Department of

Education, 2009). The lack of adequate skills and content knowledge (Wenglinsky, 2000) hinder their effectiveness (Collias, Pajak, & Rigden, 2000).

The blame for learners' poor performance rests with the quality of instruction and not learners' ability to learn (Levine, 1985); indeed this points out to teacher ability and skills. This might not always be the case there are many issues that have to be considered but for this study students' performance is used to judge the teacher's competence. It has been established that some teachers are asked to teach "science subjects they do not feel comfortable teaching and are not provided adequate guidance and support" (Chandralekha, Laura, & Christian, 2010). Teachers who are not confident in a subject cannot teach it effectively. Science teachers are not adequately prepared in scientific inquiry experiences and content knowledge (Berns & Swanson, 2000).

Teachers need the content knowledge in order to effectively deliver a science lesson when using the learner centred approach.

2.2.4 Teaching approach

The challenge in teaching science is according to Bybee (1997) that it is a practical subject and learners should use audio and visual aids as well as make observations and come up with a scientific explanation. Learners will recall better what they see and do than what they hear (Gilbert, Justi, & Aksela, 2003). Science is not all about problem solving skills and experiments but also explaining phenomena and relating them to learners' daily life experiences (Berenfeld, Pallant, Tinker, Tinker, & Xie, 2004; Nui & Wahome, 2005). Learners have different levels of skills and experiences depending on where they come from.

A teacher encounters learners from diverse backgrounds who differ in levels of motivation, skills and knowledge. It is the responsibility of the teacher to guide these learners to acquire the necessary attitudes, skills, motivation and knowledge. Also teachers have to recognise the differences between opinions of learners and scientific facts so as to guide them. Learners take control of the learning process by actively participating and discovering solutions to the problems with minimum assistance from the teacher. Learners take responsibility for their own learning (Blumberg, 2008).

Learner centeredness as a teaching approach was chosen in this study because studies have shown that successful learners are those who are exposed to this teaching approach (Lambert & McCombs, 2000). When this approach was used, learners were personally involved, committed and confident in their ability to succeed (Alexander & Murphy, 2000). The learner centred approach was chosen because it offers opportunities of assuring learners that they need to recognize that the “conceptual world” that they are exposed to in the classroom is congruent to “the world of experience” (Touger, Dufresne, Gerace, Hardiman, & Mestre, 1995). Learners should be given a chance to understand science concepts through practical activities and to relate these concepts to their daily life experiences (Park, Khan, & Petrina, 2008). This study has suggested some activities connecting their understanding of the topic and daily life experiences on the Doppler Effect which teachers and learners might find beneficial.

A learner centred approach emphasizes a variety of different types of strategies that shifts the role of the educators from givers of information to facilitating student learning (Blumberg, 2004). Learner centered approach places the emphasis on the person who is doing the learning (Weimer, 2002). The benefits of learner centered approach include increased motivation for learning and greater satisfaction with school leading to greater achievement (Maxwell, 1998; Slavin, 1990). The activities developed for learners in this study are learner centred. The following three teaching approaches have been selected on the basis that they all advocate for learner centred approach. In general, the chosen teaching approaches are basically the same as regards to their emphasis on the learners` active role in the learning process. A summary of some teaching approaches are given below:

a) Mastery Learning Approach (MLA): This is a teaching method where learners are given opportunities to demonstrate mastery of content which they were taught (Kibler, Cegala, Watson, Barker & Miler, 1981).

b) Enquiry-based approach: This approach has improved problem solving skills and has been effective at increasing student attitude toward physics (Arion, Crosby, & Murphy, 2000). With this approach the role of the learner is active participation, asking probing questions and learning the concepts by hands-on approach (Luke, 2010).

c) Activity, Student, Experiment, Improvisation (ASEI) and Plan, Do, See, Improve (PDSI) approach: This approach advocates a shift in the educator's thinking and practice from teacher centred to learner centred approaches. When teachers improvise, they demystify conventional experiments by scaling them down, thereby relating physics to everyday situations (Nui & Wahome, 2005).

This study advocates for learner centred approaches and to that effect the developed activities gave the learner the opportunity to discover the knowledge and then practically relate it to the immediate environment.

2.2.5 School environment

The school environment refers to all the physical conditions (furniture, buildings, books and equipment) and the organisation of the school (school management team). The classroom and school environment must be conducive to learning (Joyce & Showers 1988; Fullan 1991). Some schools in the Vhembe district do not have enough classrooms, furniture and the science laboratories, because they are mostly in the rural areas. The lack of resources and adequate buildings might have an effect on the learner performance and the poor grade 12 final examination results.

The school administration emphasise the need for high pass rates (Surendra, 2001) and the Vhembe district is no exception. This could result in teachers using teaching approaches which are examination focused. Darling-Hammond (1997) indicated that conditions in some schools have forced teachers to acquire survival tactics at the expense of effectively delivering the science content.

Foreign teachers' future at a school is dependent on the pass rate of his/her learners at the NCS examinations, and this is the practice in Limpopo province.

This study has its limitations in addressing the school environment. However, it addresses the professional development of teachers with regards to their content knowledge and teaching approaches of teaching the Doppler Effect to grade 12 learners. The study also explores some of the teaching and learning problems revealed in other researches on the Doppler Effect.

2.3 Other research on the teaching and learning of the Doppler Effect

In their study, Flick & Bell (2000) have confirmed that many scientifically accepted ideas are not easy for learners to understand due to their complexity, abstract nature and/or contrariness to experience and common sense. For example, learners cannot see the change in the wavelength of a sound wave; this shows the abstract nature of physics where things can only be perceived with the aid of science equipment or inferences (Mbajjorgi & Reid, 2006). As a result of this abstractness, physics is perceived as a difficult and an uninteresting subject (Fonseca & Conboy, 1999). Furthermore, Flick & Bell (2000) stressed that the simulations on the Doppler Effect allow learners to manipulate various components such as speed of object, speed of sound and frequency of sound emitted by object. As a result learners will ask themselves questions, try out ideas and draw their conclusions.

The problem faced by learners with the Doppler Effect is that it requires simultaneous understanding of the spatial and time dependence (Gimenez, Vidaurre, Riera, & Monsouriu, 2008). It follows that the traditional teaching resources such as slides, overhead projector with transparencies and the blackboard are no longer sufficient to teach the Doppler Effect. Also in his study Papacosta Pangratis (2010) emphasised the need for visual demonstrations or simulations on the topic like the Doppler Effect.

2.4 The Doppler Effect

The Doppler Effect is the apparent change of frequency and wavelength of a wave when the source or the observer moves relative to each other (Gibbs, 1997). When dealing with sound, if a source of the wave (car sounding a siren) and an observer are moving relative to each other, the observed frequency is different from the source frequency. When the source and observer are moving away from each other, the observed frequency is less than the source frequency. This is due to the sound waves being stretched to create lower frequency sound waves. When the source and observer are moving towards each other, the observed frequency is greater than the source frequency. In reality the sound waves are being compressed, causing a higher frequency to be heard by the listener/observer. This phenomenon is called the Doppler Effect. A familiar example is the change in pitch of an ambulance siren when

the ambulance is approaching or receding. This relationship can be summarised mathematically by the equation:

$$f_i = \frac{v \pm v_l}{v \pm v_s} f_s$$

Where

v = speed of sound in the medium

v_s = the velocity of source of sound

v_l = the velocity of observer

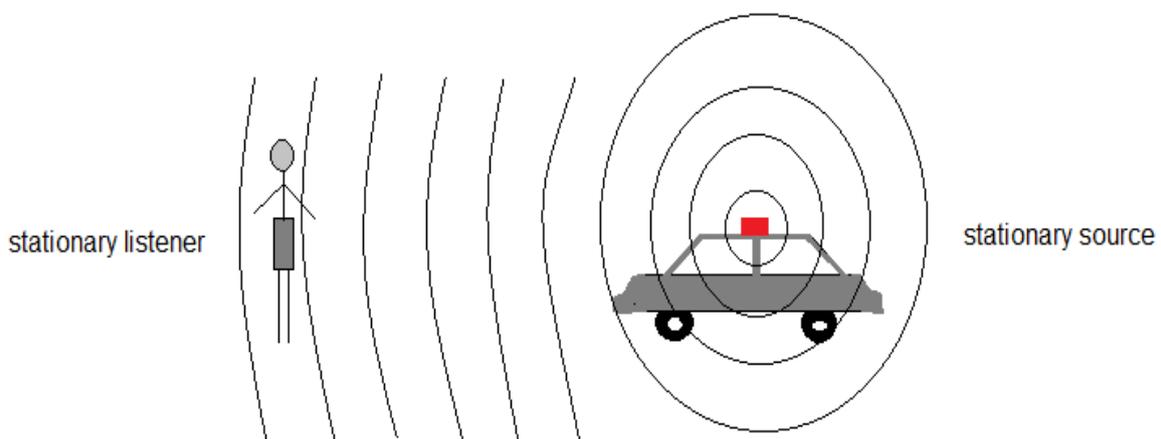
f_s = the frequency emitted by source of sound

f_i = the frequency heard by the listener

In reality the velocity of the wave remains constant whereas the wavelength changes; hence frequency will also change.

Scenarios illustrating the Doppler Effect:

1. Stationary source , stationary listener



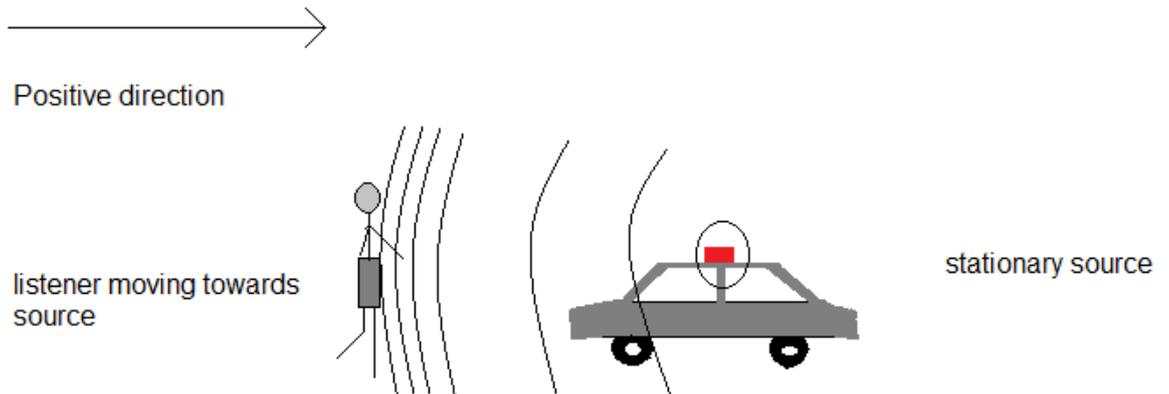
$$f_i = f_s$$

The frequency heard by observer is equal to the frequency emitted by the source if they are close together.

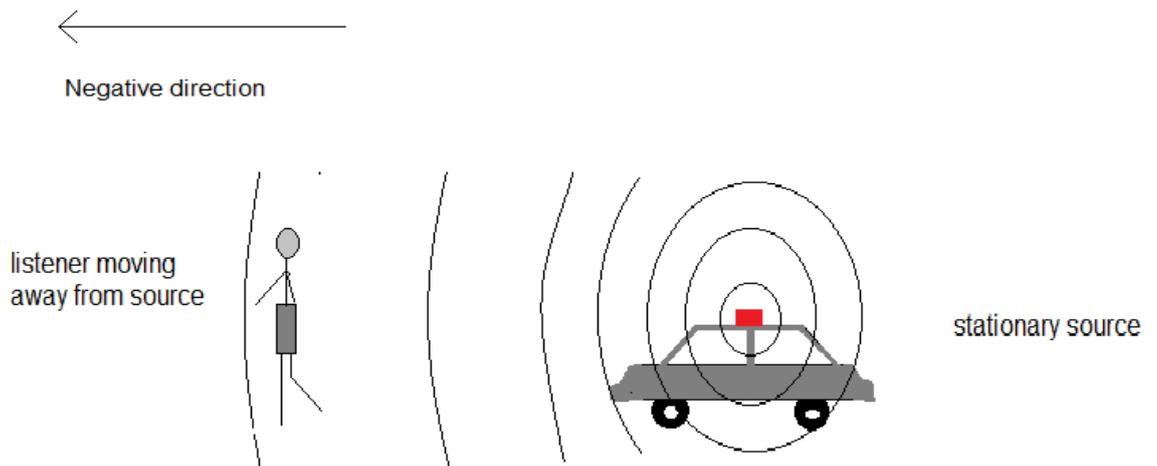
2. Moving listener, stationary source

$$f_i = \frac{v \pm v_l}{v} f_s$$

- the plus sign applies when listener moves towards the source as shown below:



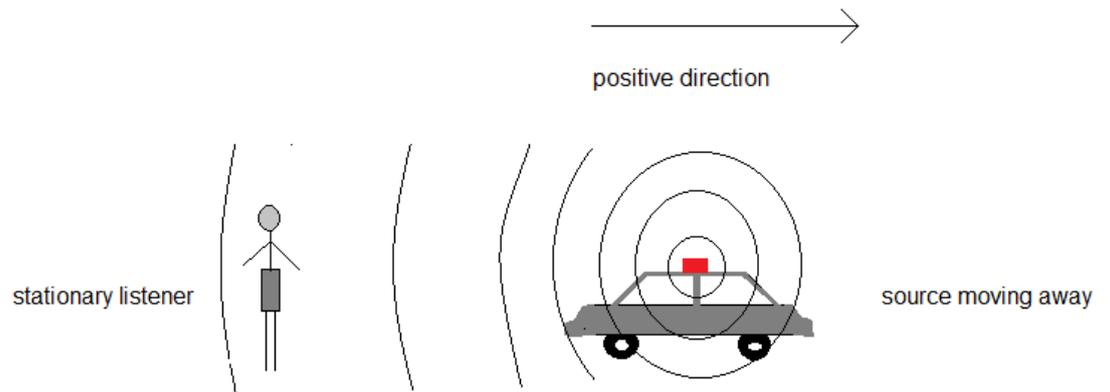
- The negative sign applies when the listener moves away from the source of sound.



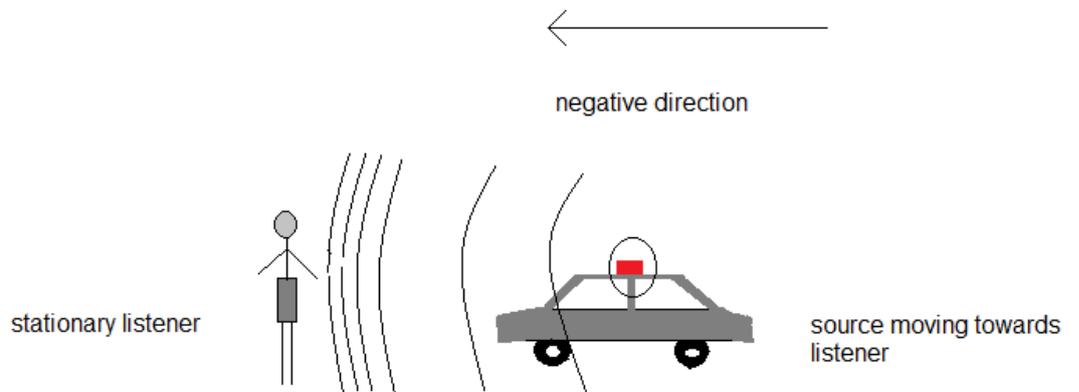
3. Stationary listener, moving source

$$f_i = \frac{v}{v \pm v_s} f_s$$

- the plus sign applies when source moves away from the listener



- the negative sign when source of sound moves towards the listener



4. Moving listener, moving source

$$f_i = \frac{v \pm v_l}{v \pm v_s} f_s$$

- the upper sign positive and lower sign negative apply to source/ listener moving towards each other.

- The upper sign negative and lower sign positive apply to listener/source moving away from each other (Lowe & Rounce, 1997).

2.5 The Doppler Effect: Light and sound

The Doppler Effect is sometimes included when the topic sound is discussed and sometimes when the topic light is considered. There are two reasons for the difference in the application of the Doppler Effect for sound and light waves. Firstly, the sound waves are mechanical and they require a medium to travel through. Secondly, the velocity of light waves is the same in all inertial frames of references but the velocity of sound is not. The formula;

$$f_i = \frac{v \pm v_l}{v \pm v_s} f_s$$

applies to sound waves, if and only if the speeds of the source of sound and the observer relative to the medium are slower than the speed of sound (Lowe & Rounce, 1997).

However, the Doppler Effect is also included under the topic light where the speed of the wave is far greater than the relative speeds of source and observer, the example is that of electromagnetic waves, the Doppler Shift. The Doppler Effect for electromagnetic waves like light is used in astronomy to show a red shift or a blue shift. The spectra of stars are not continuous; instead they exhibit absorption lines that are not always at the frequencies that are obtained from the spectrum of a stationary light source. Red light has a lower frequency than blue light, the spectral lines of an approaching astronomical light source exhibit a blue shift and those of receding light source exhibit a red shift. This has helped scientists to realise that galaxies were moving away, and therefore they could conclude that the universe is expanding. Studies have indicated the need for making real world connections when physics is being taught (Hazari, Sonnert, Sadler, Marie-Claire Shanahan, 2010).

It was important to come up with a practical solution to the challenges faced by the teachers; therefore a comprehensive theoretical framework was needed to work on in order to have a solution that can be adopted elsewhere.

2.6 Theoretical Framework

The study is to address the challenges experienced by teachers when teaching the Doppler Effect by designing learning activities on the Doppler Effect with the aim of promoting learner centred approach in learning.

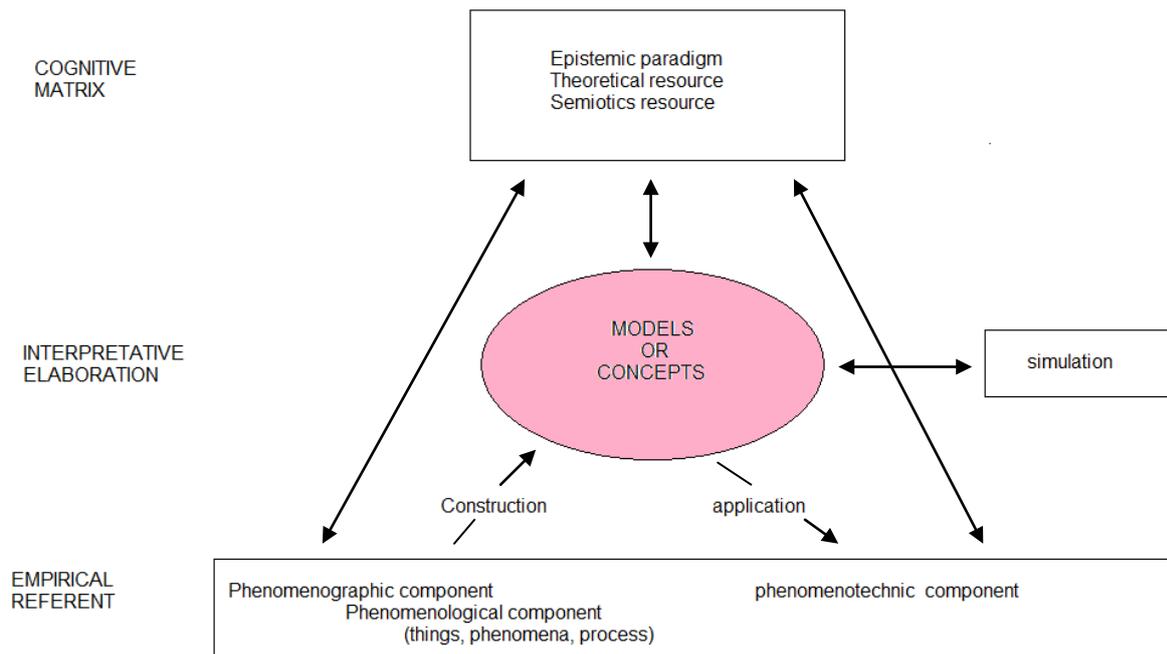
A theoretical framework attempts to connect to all aspects of inquiry like statement of the problem, purpose of study, literature review, methodology, data collection and analysis of results. Frameworks help us to “visualize the problem, to break it down into discrete, manageable units” (Ryder, 2011). The designers in the design research should come up with a model for learning the topic of interest (Clements & Battista, 2000). The focus of this research was to design learning activities on the Doppler Effect with the aim of promoting learner centred approach in learning.

There has been a significant shift in theories of learning from the objectivist view to the constructivist view and this has had an impact in the teaching and learning of science. The objectivist view as described by Hendry (1996, p 24-25) is the teaching and learning in which the teachers possess the “knowledge” and the learners “are expected to listen and/or watch”. According to Ng`ambi & Johnston, (2006) the teacher was viewed as a fountain of knowledge.

The constructivist view holds that the learners construct knowledge for themselves (Hein 1996). Learners learn new concepts by constructing or building on their prior understanding (von Glasersfeld, 1983). Furthermore Erickson (2007, p 7) notes that learners are “capable of constructing plausible conceptions while engaging with their physical and social worlds”. A constructivist perspective holds that learning occur when learners construct their own meanings in a unique way whilst interacting with their learning environment and building on their existing knowledge (Killoran, 2003; Ping 2002).

This study is framed by the Martinand model (figure 1) as cited in Ganaras, Dumon & Larcher (2008). The links between practice and theory are important in the building up, organisation and the integration of scientific knowledge (Ganaras et al., 2008). The theoretical framework (figure 1) analyses the dialectic link between experiments, models and theory that is experienced by learners during their construction of knowledge.

Figure 1: Martinand`s science model



The empirical referent:

The empirical referent consists of real objects and phenomena and also includes rules of action on these objects and phenomena. The empirical referent has been divided into three components as follows:

- i) Phenomenotechnic component; this is the experimental ability, knowledge of laboratory apparatus and laboratory safety rules.
- ii) Phenomenographic component; refers to the ability to describe objects and phenomena so that related information can be communicated.
- iii) Phenomenological component; corresponds to another description in terms of concepts, models and shared theories.

The interpretive elaboration:

This is what is created with the use of models and concepts in order to represent the empirical referent.

The cognitive matrix:

It consists of the epistemic paradigm and the theoretical resource (language, drawing, theories and symbols). Cognitive matrix is a set of theoretical and experimental knowledge of a learner's operational knowledge (Ganaras et al., 2008).

I used this scheme in the phrasing of the questionnaires and interview questions, developing of EDR activities and data analysis. The learners in this study were in the final year of school and it is assumed that they should have cognitive matrixes which allow them to link the Doppler Effect phenomena and explain the empirical referent in using the developed EDR activities and theories. According to the theoretical framework, the empirical referent is divided into three components. The phenomenotechnic component includes the knowledge of the apparatus used in the activities which are a slinky, eyedropper and bicycle. The phenomenographic component includes the description of an empirical referent in terms of the Doppler Effect concept, while the phenomenological component consists of the description of the same empirical referent in terms of concepts and notions, resulting from some past conceptualization (water waves, frequency, wavelength and speed of a wave etc). The EDR activities were used to uncover how far the learners' experimental knowledge has been improved by this concept.

Several factors have been identified as important to the problem such as teacher content knowledge, laboratory equipment and teaching approaches, this framework will assist in making logical sense of these factors (Sekaran, 2000). This theoretical framework was utilized in this study through the use of designed activities to create an environment that will help learners reach their level of potential development. The learners worked in groups gaining what Solomon (1987) in Hand & Vance (1995, p 41) calls "a public forum for both testing their knowledge and extending and expanding it" through practical activities and group discussions. The designed activities will help learners understand beyond what they already know because they will be actively involved and they will be constructing their own knowledge. EDR activities can help learners to discuss in a collaborative way in the classroom and their performance could be enhanced (Ingvarson et al, 2004).

2.7 Summary

The chapter started with a brief explanation of the challenges faced by the teachers. The theory of the Doppler Effect was presented as well as why it is sometimes included when the topic light is discussed and sometimes when the topic sound is presented. Finally the theoretical framework was presented and explained.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the research design, population and sample of the research, validity and reliability of instruments, procedures for data collection and data analysis methods. A discussion of ethical issues considered in this study is also included.

3.2 Research Design

This study incorporated a qualitative and quantitative approach when collecting and analysing the data. It is recognised that all methods have limitations and that using a range of research methods allows for triangulation of data sources. In this way, the study used questionnaires and interviews to establish the baseline. Activities were designed and the evaluation of these involves determining the worthiness, merit or the quality (Johnson & Christensen, 2000) of the designed activities. Educational design research sometimes called design based research was used and it possesses an iterative design characteristic (Cobb, 2003).

A quantitative approach namely the explanatory research design (Creswell, 2008) was used to determine the association between the final products namely the developed activities and the written tests.

3.3 Research population and sample

The sample of the study was purposefully (Babbie & Mouton, 2009) selected so as to get as much useful information as possible. A total of 12 secondary schools in Vhembe district in Limpopo province were chosen for trying out the designed lesson activities.

Although the Vhembe district has 27 circuits, only three circuits namely; Luvuvhu, Mvudi and Sibasa were selected for this study. The 3 circuits were purposefully chosen because of their proximity to each other which reduced transport costs during the distribution and collection of questionnaires. Therefore the sampling is both purposeful and convenient. Two schools (one rural and another urban) were chosen for piloting the activities and 10 schools for evaluating the refined activities.

Table 4 below indicates the circuits and the number of schools which were chosen for this study.

Table 4: The circuits in Vhembe which were chosen for the study

Circuit	No of Schools
Luvuvhu	10
Mvudi	13
Sibasa	11
Total	34

A total of 32 teachers completed the questionnaires and one subject advisor was interviewed. A total of 216 learners were used in the study and were taught by the selected teachers.

3.4 Instruments

In order to answer research question 1; Which aspects of the topic Doppler Effect do the teachers find challenging?

- a) What are the challenges identified by the teachers in terms of content knowledge when teaching the Doppler Effect to grade 12 learners?
- b) What are the challenges identified by the teachers in terms of teaching approaches when teaching the Doppler Effect to grade 12 learners?

A questionnaire for teachers (appendix 1) was developed and an interview with the subject advisor (appendix 2) was conducted. To answer research question 2, which says; What is the effectiveness of teaching the Doppler effect using developed learner-centred activities?

Students' activity sheets (see appendices 4, 5 and 6) were developed by the researcher and completed by 41 learners who also wrote a test. A total of 41 learners were used in the pilot study. After analysis changes were made, and the activity sheets were distributed to and completed by 216 learners. A total number of 216 learners completed the activity sheets and wrote a test on the Doppler Effect.

3.4.1 Questionnaires

A questionnaire was developed to establish the baseline of what the challenges are in teaching the Doppler Effect to Grade 12 learners. The disadvantages of this questionnaire were that it failed to give answers to such questions as, when? why? and how? (Bless & Higson-Smith, 1995). The questionnaire (see appendix 1) comprises of 18 questions and was used to obtain information on:

- teacher background: qualifications and teaching experience
- the teaching approaches used by the teachers on the topic the Doppler Effect,
- challenges experienced when teaching the topic Doppler Effect,
- whether the teachers make use of practicals/demonstrations/activities during their lessons with regards to the Doppler Effect or not.

As pilot, six copies of the same questionnaires were distributed to grade 12 physical science teachers who were not part of the sample. The teachers were conveniently selected from six different schools rural, semi-rural and urban schools in the same district. Two separate cover letters from the University of South Africa (UNISA) and the Department of Education were attached to the questionnaires to authenticate them and to ensure that due process is followed.

These teachers were given a week to complete the questionnaires which were then collected by the researcher. A total of 32 questionnaires were completed (out of the 34 questionnaires that were sent out) and collected by the researcher from these selected schools. The percentage of questionnaires returned was 69.6%.

Reliability

The questionnaire was checked for accuracy and consistency using the pilot study. The internal consistence of the questionnaires was verified by using the split-halves reliability method (Bless & Higson-Smith, 1995).

The items of the questionnaire were split into halves, the first half with odd question numbers and the second half with even question numbers. The number of piloted copies were 6 and this gave a total of 108 (6x18) questions. Therefore there were two groups of items each with 54 (108/2) questions. The teachers responded similarly to the groups of items, indicating reliability and that the instrument has high

internal consistency. When analysing the items it was found that no items were giving conflicting results and therefore all the questions were maintained.

Validity

After piloting the questionnaire, the aim was to check if the instrument is measuring what it is supposed to be measuring, and to determine if the answers given by teachers have any meaning. The instruments were pilot tested in the field to ensure instrument validity and to check on clarity of instructions and relevance of items (Bless & Higson-Smith, 1995).

Content validity:

Before questionnaires were constructed a study of the literature related to the Doppler Effect was done focusing on the content and teaching approaches as this is part of the research questions. Various text books were read on the topic Doppler Effect. This was done to make sure that the questionnaires are contextually correct.

External validity:

The questionnaires were distributed to 34 schools out of a population of 46 schools in the chosen cluster of schools because of their location. The 34 schools were not amongst the 6 schools chosen for pilot study. The questionnaire was completed by 32 of the 34 teachers given the questionnaire. The percentage of the teachers who participated was 94.1%, therefore the result of the baseline can be generalised as representing the cluster. The actual number of schools in the cluster which participated in the study was 32/46, giving a percentage of 69.6%.

Construct validity:

The process of constructing the questionnaire began by listing different ideas about the information which were to be uncovered by the questionnaire so as to establish the baseline. There was a link between the items in the questionnaire and the sub research questions (a) and (b).

Face validity:

The questionnaire was intended for the physical science teachers and correct scientific terminology was used to ensure that it was relevant to them. The analysis

of the piloted questionnaires led to the conclusion that; the instrument was not too difficult, too long, or too simple for the testees, and they found it easy to understand.

3.4.2 Interview

One subject advisor was interviewed because he was the only physical science subject advisor covering the area of study. Before the interview was conducted, the interview protocol was taken to two lecturers experienced in training physical science teachers at university, for moderation. This was done to remove any ambiguity from the interview protocol. These lecturers were chosen because they visit schools when their students are on teaching practice and they are familiar with the context. All this effort was made to come up with valid information from the subject advisor. In addition, 3 of the 32 teachers and 3 of the 216 learners were interviewed after the lessons to probe them on the lessons and thereby ask clarity on some of the observations. Only few learners (3/216) and teachers (3/32) were chosen, this was done for convenience purposes; there was no need for many interviewees since no inferences were intended to be drawn from the interviews. The teachers and learners were randomly selected. The learners had to indicate if they understood the lesson, enjoyed the activities and if the equipment were user friendly as well as evaluate the lesson in terms of teaching approach. The envisaged purposes of interviews were:

a) Learners:

- ✓ to check if learners understood the lesson
- ✓ to verify if there was any difference in teaching approach from what they were used to
- ✓ Evaluate the lesson

The teachers had to comment on the teaching approach, the learner centeredness of the activities. Also teachers had to express their observations and comment on the effectiveness of the activities and if they would desire to adopt the teaching approach.

b) Teachers:

- ✓ To verify on whether the teachers benefited from the activities

- ✓ To comment on the lesson activities.

Since the sample was small no inferences were made.

3.4.3 Activity sheets

The lesson objectives and how the activities were constructed are shown in appendix 3. The three chosen activities which addressed the main aspects of the Doppler Effect are:

- a) The relationship between frequency and wavelength
- b) The apparent change in frequency of sound when there is relative motion of the listener and the source of sound.
- c) Correct use of the Doppler formula and its application in solving problems.

It was difficult to call for a meeting with the teachers therefore the researcher had to visit the 12 teachers (2 for pilot and 10 for the refined activities) concerned in order to demonstrate to them how to do the activities. Some teachers asked for equipment which they did not have in their schools and these were supplied by the researcher. During the pilot study it was possible to note the needs with regards to equipment and adjustments like using the pipette instead of eye dropper were made to the activities. Activities were piloted in 2 different schools, one being a rural school and the other being an urban school. The lessons were specifically conducted in such a way that the learning environment of the learners was not changed so as to eliminate bias from the learners. The schools which were selected were far apart so that the learners would not share the contents of the lesson activities since the lessons were conducted on different days. After the learners had done the activities and completed the activity sheets challenges encountered such as poor visibility of waves on cafeteria trays were noted and modifications were made to the activities and accompanying activity sheets, before it was distributed to the 10 schools.

3.4.4 Tests

Learners in this district were subjected to writing the same test as described in paragraph (1.2). Therefore, all schools wrote the same test with the same weighting of marks. The questions were relevant to the curriculum and similar to those

questions set for the final examinations. The answered sheets were collected, marked and analysed by the researcher.

Relationship between activity sheets and tests:

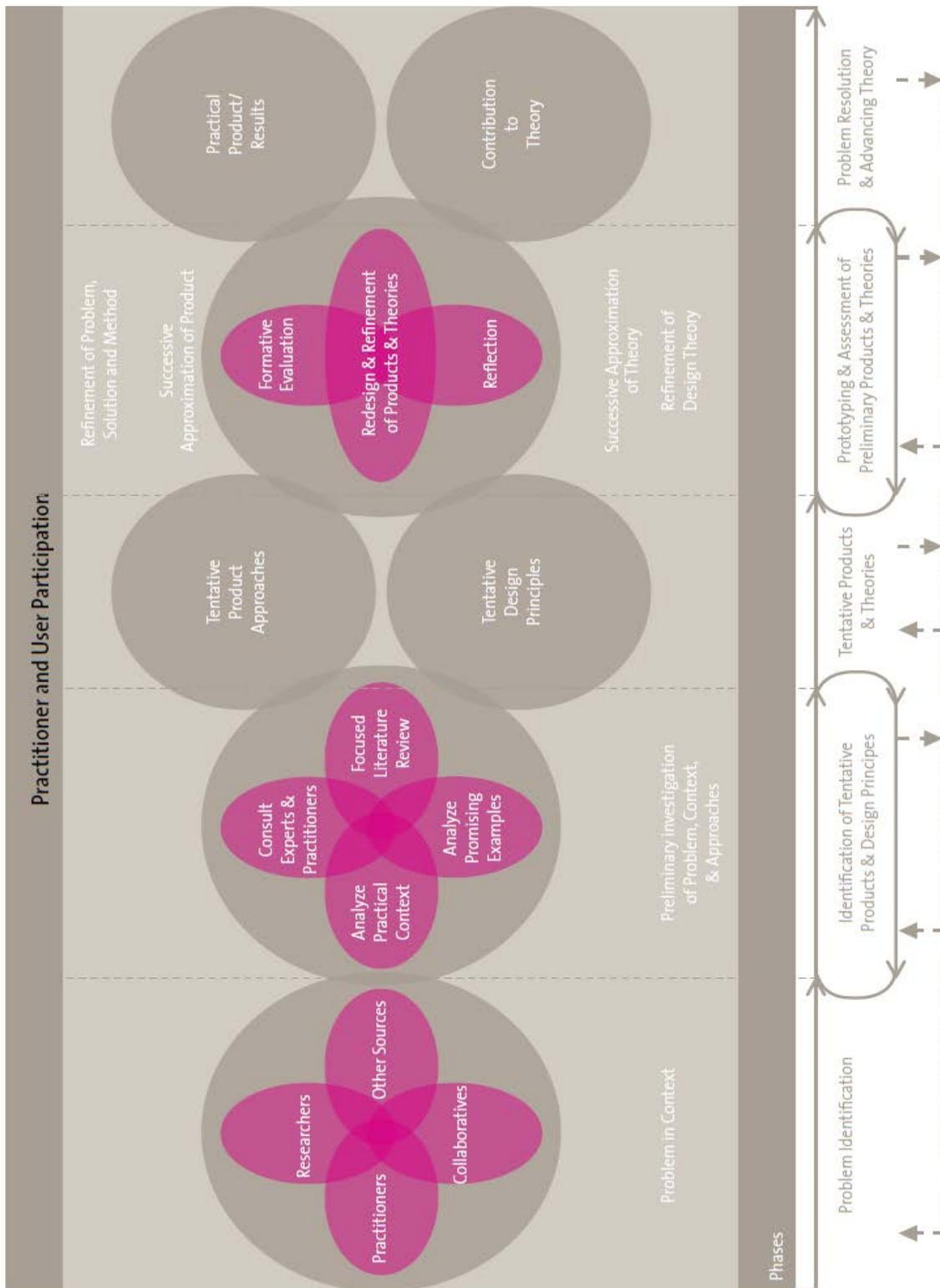
- Both the activity sheets and tests were on the same topic, the Doppler Effect.
- The learners carried out the activities performing the experiments by themselves and the tests were used as a measure of learning gains.
- The scores from marked activity sheets and marked tests were compared to find out if there was any correlation between the two.

3.5 Methodology

The study aimed at producing high quality developed activities designed to solve an educational problem. The activities were use-inspired (van den Akker, 1999) and were specifically designed for the teachers and learners in grade 12.

Systematic educational and instructional design processes are cyclical in character: analysis, design, evaluation and activities are refined in an iterative manner until a satisfying model was obtained. This study has used the Generic Design Research Model (figure 2) as described by Wademan (2005).

Figure 2: Generic Design Research Model (Wademan, 2005).



Description of the steps used in the methodology (figure 1):

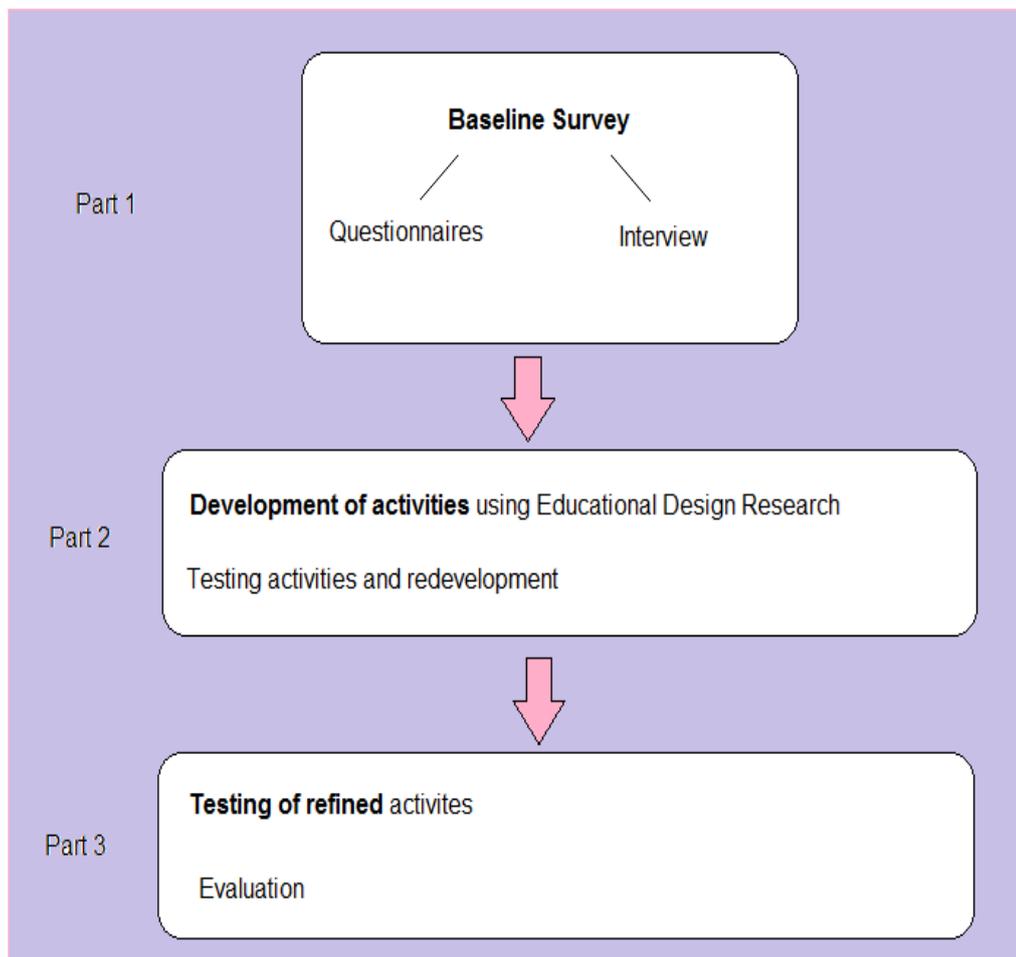
1. Problem identification

The challenges of teaching the Doppler Effect to Grade 12 learners in the Vhembe District were identified as the problem of the study.

2. Preliminary investigation of problem, context and approaches.

The study has been done in three parts (see figure 3). The first part was to establish the baseline by distributing questionnaires to teachers and conducting an interview with the subject advisor. This was to establish the challenges faced by teachers and determining the teaching approaches they used. The second part involved the development of activities using Educational Design Research (EDR), then the trying out of the activities and then the redevelopment of the activities. The third part comprised of the testing of the activities in 10 schools. After the evaluation of these activities an Instructional Manuel on teaching the Doppler Effect was developed and distributed in the district.

Figure 3: The three parts of the study



3. Tentative products and theories

After analysis of the questionnaires information on the challenges which the teachers have when teaching the Doppler Effect were documented. A possible solution had to be found to address these challenges. The design-based activities were chosen as a possible solution because they integrate all three Learning Outcomes as well as present knowledge and alternative teaching approaches. The researcher's goal was to come up with refined activities which could be used to assist teachers and learners in the topic Doppler Effect.

4. Refinement of problem, solution and method.

Both formative and summative evaluations were used. Formative evaluation was used to improve and to uncover shortcomings of the activities during their

development. Summative evaluation was used to gain evidence for the effectiveness of the developed activities (Nieveen, 2007). The activities were initially tried out in 2 schools. Challenges faced in trying-out the activities were noted, for example some schools did not have the required apparatus. Changes were implemented and the activities were then modified. The final product was then tried-out in 10 schools.

5. Refinement of design theory

The researcher reflected on the performance of the learners and evaluated the effectiveness of the activities in achieving lesson objectives. The evaluation was done to improve the activities to a high quality product.

6. Problem resolution and advancing theory.

The challenges of teaching the Doppler Effect were identified. Activities were developed to assist the teachers and learners on the teaching and learning of the Doppler Effect in grade 12. **An instructional manual** was produced after all necessary improvements were incorporated.

3.6 Development of Doppler Effect activities

The activities of this study were developed using mainly a cited article (Patterson, 2007) and the textbook Focus on physical science grade 12 (Hendricks, Sadeck & Spies). The Patterson approach was used, for developing activities which allowed the learners to predict, observe and explain the phenomena.

He has produced a lesson plan with activity sheets on the Doppler Effect for use in a secondary school (Orion Jr. High) covering the course; Earth Systems. The core curriculum standard or aim of his activities was: "Students will understand the scientific evidence that supports theories that explain how the universe and solar system developed". One of the intended learning outcomes was to, "Observe objects, events and patterns and record both qualitative and quantitative information". The research questions to be scientifically investigated by learners were:

1. *What factors affect the wavelength of a wave?*
2. *What is the Doppler Effect?*

In Patterson`s lesson the teacher is instructed to start out with a class discussion of how learners think the universe might have been formed and to list reasons why they think the universe was created that way. Learners were encouraged to discuss ways science has tried to explain the formation of the universe. However, the approach is different from the way it is done in the South African secondary schools.

In South Africa, one of the text books used by teachers and learners is “Focus on Physical Science grade 12” (Hendricks et al., 2007, p 54). The only activity suggested in this book for the Doppler Effect is a practical demonstration done outside the classroom. The following are the instructions taken from the text book:

Your results will be more reliable on a windless day.

You will need:

- *a bicycle*
 - *a referee whistle*
1. *Have the class group stand 50m away from a pair of learners on the bicycle. One of them will be cycling. While lifting the other learner, who will be blowing the whistle.*
 2. *Start cycling towards the class group, while the whistle is being blown. Take care to blow the whistle steadily, not softer or louder. (Practice blowing at an even level before the actual demonstration).*
 3. *Carry on cycling, with the whistler still blowing, until you are at least 50m past the class group.*
 4. *Write a short report about this experiment in your workbook. Record all your observations.*
 5. *Provide a possible explanation for what you observed.*

An additional three activities were added and the one for the bicycle modified. A learner might not be able to blow the whistle steadily and so an electronic device (cell phone) was used. In order to link science with the everyday experiences of the learners another activity was designed for the learners to observe the change in sound frequencies when the vehicles pass by the road (see table of activities,

appendix 3). The developed activities have incorporated the main ideas of the three teaching approaches (mentioned in paragraph 2.2.4). The learners had to demonstrate their knowledge of water waves which they were taught earlier (Mastery Learning approach) and the learners were to actually perform the experiments by themselves (Enquiry-based approach). The materials used for the activities were readily available within the learners` environment and were relating to the learners` everyday experiences.

3.7 The advantages of using Educational Design Research

Educational Design Research (EDR) is an effort that “seek to understand learning and influence educational practice” and “pursues the goals of developing effective learning environments as natural laboratories to study and teaching” (Sandoval & Bell, 2004). In addition EDR helps to bridge the gap between research and practice (Romme, 2003; Van Akan, 2004). Learners tend to recall more when they learn hands-on using activities (Berenfeld et al., (2004). Hegarty-Hazel (1990) points out that the activities allow learners to develop technical skills and the manual expertise needed when carrying-out experiments.

EDR brings out different kinds of knowledge together with a better theoretical understanding of the learning aspect that can be addressed by an intervention and ability to use effective design practices (Design-Based Research Collective, 2003; Edelson, 2002).

In this study, EDR was used to identify problems faced by learners, teachers and researcher because it gives new knowledge about science teaching and learning. The activities were developed and tested, refined and re-tested in an iterative cycle and finally an instructional manual were developed. The practical contribution of EDR in this research is that it has produced tangible products that can be adopted elsewhere (Barab & Squire, 2004).

The decision to use EDR instead of Action Research was based on the following features that EDR possess (Juuti & Lavonen, 2006);

- i. A design process is essentially iterative.*

- ii. *Objective of the Design Research is to develop an artefact to help teachers and learners to act (teach and study) more intelligible (in a way that advance learning).*
- iii. *Design research renders novel knowledge about science teaching and learning.*

Action research has disadvantages of; development of a solution to a practical problem (Plomp & Nieveen, 2007), personal over-involvement, it is time consuming and complex to conduct. Design activities were developed because they give rise to positive scientific attitudes leading to open-mindedness and the power for critical judgement (Friedler & Tamir 1990).

The following observation is like a wakeup call to all of us;

“unless we are willing to apply the same rigorous standards of scholarship to issues related to learning and teaching that we regularly apply in more traditional research, the present situation in physics education is unlikely to change” (McDermott, 1998, p 8)

In an attempt to change this present situation when learning and teaching the Doppler Effect, the core of this study was to develop learning activities and trying them out by using the EDR. The developed activities are easy to use and they utilise simple materials which are easy to manipulate. When EDR is tested with action research, relevant knowledge is produced for practice and theory (Andriessen, 2007). EDR must offer something new, of interest and useful to the stakeholders as emphasised by Edelson (2002, p 118),

“A design [-based] research program should yield new theories (for this study an instruction manual) that have utility for resolving important problems”

This research has offered an instructional manual for the use by teachers and learners.

3.8 Data analysis

In this study, qualitative and quantitative research methods are complementing each other.

Quantitative data

The sources of the quantitative data are the teachers' questionnaire as well as marks from activity sheets and tests. The data from questionnaires were analysed using graphs and statistical calculations such as mean, percentages and correlations using the software SPSS with the aim of justifying conclusions. In order to use statistics programme SPSS for data analysis answers to individual questions were organised. Before analysing the data, key points in the answers from questionnaires were noted and codes were developed which describe separate categories of similar answers. The computer was then able to manipulate the data using the codes (see Appendix 7 and 8). The tests written by 216 learners were marked and the marks analysed. In order to find a relationship between the marked activities and the written tests, correlation analysis was carried out.

Qualitative data

The sources of qualitative data were the learners', teachers' and the subject advisor interviews. The researcher randomly selected the 3 learners and 3 teachers for interviews. There was only one subject advisor appointed in the District where the research was carried out and he was also interviewed. The interviews were transcribed.

3.9 Ethical considerations

3.9.1 Official permission

An application was done (see appendix 9) to the Department of Education in Vhembe district Limpopo province to conduct research with the selected Grade 12 learners, teachers and the subject advisor. Permission was granted (see Appendix 10A). The permission letter indicated that the researcher was to inform the Circuit Manager and Principals of schools before visiting their schools. The Department also emphasised that the interaction with the learners and the teachers should not disrupt teaching and learning activities in schools. Permission was sought from the Circuit Manager and school principals concerned.

Also students conducting research as part of their studies in the Institute for Science and Technology Education are required to seek ethical clearance from the UNISA

Ethical Review Committee. An application for ethical clearance has been made and approval has been granted (see Appendix 10B).

3.9.2 Subject Advisor, teachers and learners.

The subject advisor was notified about the purpose of the study and willingly agreed to be interviewed (see appendix 2 for interview schedule).

The teachers completed the questionnaire voluntarily. The learners were not aware that a research was carried out in their schools because nothing unusual happened during class time.

To ensure that these learners and their teachers were protected from any victimisation, biases and any infringement of their rights, the information collected in this study will not be used to disadvantage the participants in any way. Teachers and learners were assured that their names were not to be used in this research.

3.10 Summary

This chapter presented the research design, research population and sample. It also presented the instruments used, methodology, data analysis and finally the ethical considerations. The data collected and analysis will be discussed in the next chapter in order to answer the research questions.

CHAPTER 4: PRESENTATION AND ANALYSIS OF DATA

4.1 Overview

This chapter focuses on the presentation and analysis of the data. The data were collected in three phases in order to answer the two research questions.

Phase 1: In order to establish the baseline and answer research question 1, data were collected from grade 12 physical science teachers about their background, content knowledge with regard to the Doppler Effect, what teaching approaches they use as well as the support they receive. An interview was conducted with the subject advisor to seek amongst others for his explanation on the poor performance of learners in grade 12 physical science. Quantitative and qualitative analysis of the questionnaire were done and only a qualitative analysis of the interview was done.

Phase 2: The activities were developed and tried out in 2 schools in order to answer sub question 2. The completed activity sheets and written test were collected from learners and were analysed by quantitative means. In order to minimise the 'leaking' of the test the 2 schools whose learners wrote the pilot test, the schools were far from the 10 schools whose learners wrote the test on the same day. Improvements were made to the activities; the refined product was ready for the next phase.

Phase 3: The altered activities were tried in 10 schools and again the completed activity sheets and written test were analysed quantitatively.

4.2 Phase 1: Results and analysis of the questionnaire for teachers

Teachers had to complete a questionnaire with 18 questions. The questionnaire comprised of closed-ended questions which required a teacher to tick an option, and open-ended questions (see appendix 1). The theoretical framework guided the phrasing of the questions in order to get information from the teacher on the "phenomenotechnic" aspect (see paragraph 2.6). That is, the teachers' ability to use laboratory equipment. There were questions on the "Phenomenographic" which required the teacher to describe how the teacher communicates information (teaching approach) on the Doppler Effect to the learners. There were questions on

the cognitive matrix level of the framework (questions on the Doppler Effect formula) which required the teacher to use rationality, symbols and theoretical ideas in order to answer them.

The teachers` background was used to determine information on their gender, years of teaching experience and qualifications (certificates, diploma or degrees). This information is important, since studies have revealed that teacher` qualifications correlates positively with learners` achievement (Betts, Zau, & Rice, 2003).

Personal Information

1. Gender N=32

Table 5: Gender

Male	30
Female	2

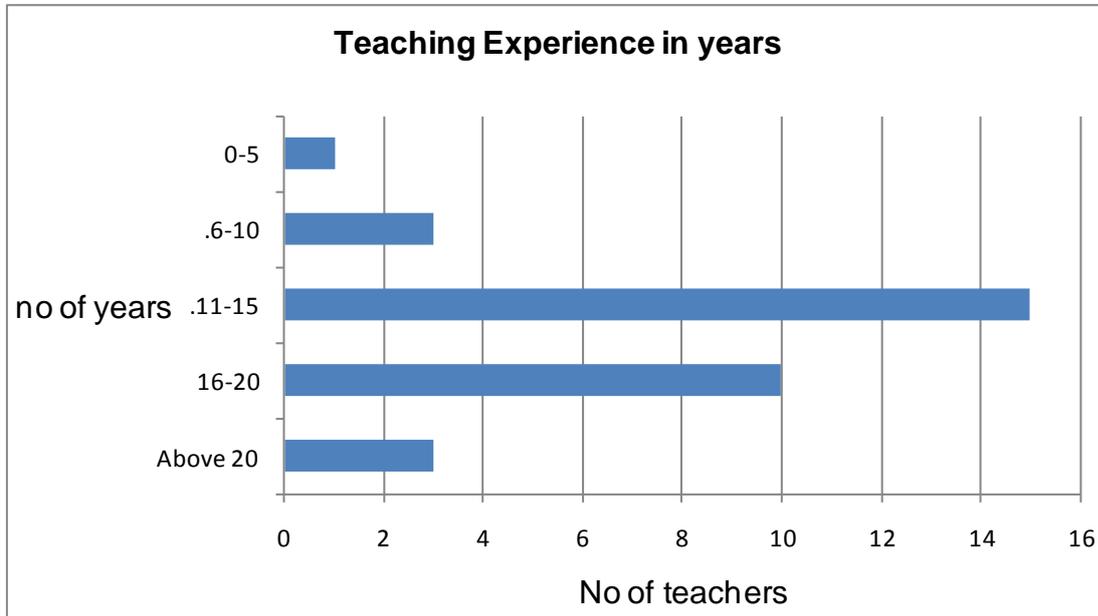
The analysis of the questionnaire (see appendix 1) indicates that 30 males are teaching physical science and only 2 females are teaching the subject in grade 12 (see table 5). This is not the situation in Vhembe alone, and also it is not unique to South Africa. The United Nations Educational, Scientific and Cultural Organisation (UNESCO, 1999) has recognised the issue of women in science as a global challenge (UNESCO, 1999). Women are being sidelined when it comes to education and training in science and engineering (UNESCO, 1999). In Latin America, Caribbean and Africa women have difficulty in accessing education and are rarely in hierarchical posts or at decision-making levels (UNESCO 2). In United Kingdom, only 3-4% of professors in any branch of Science, Engineering and Technology (SET) are women (Gavaghan, 1997).

2. Grade 12 physical science teaching experience in years

The results show that of the 32 teachers who completed the questionnaires, 28 teachers (87.6%) have more than 10 years experience (figure 4). This information is

important because studies which were carried out at secondary schools have shown that teachers experience correlates with learners' achievement (Betts et al., 2003).

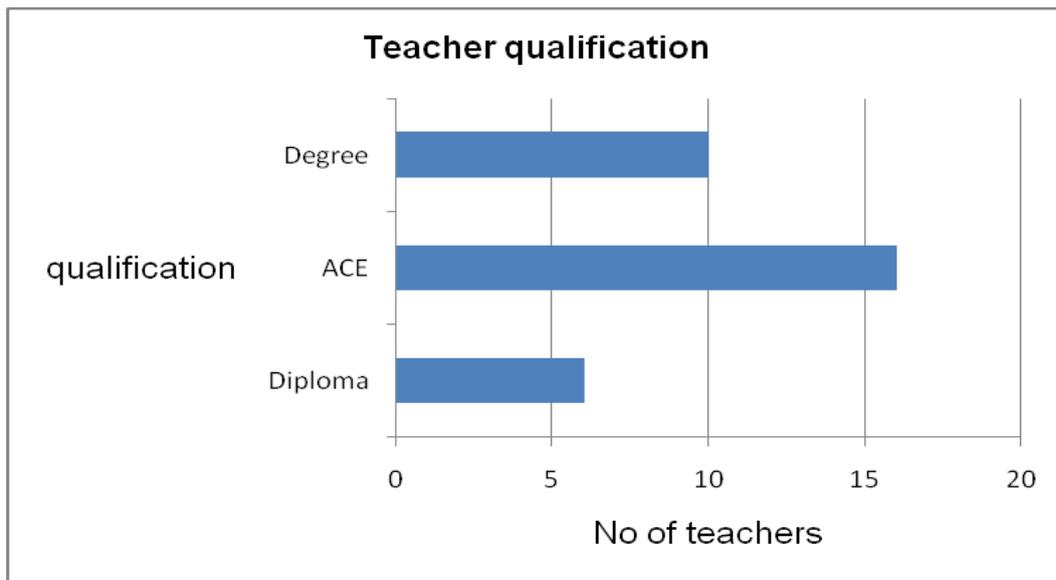
Figure 4: Teaching experience



3. Teacher qualifications

A diploma referred to in this questionnaire was a science teaching diploma (2 - 4 years training). The Advanced Certificate in Education (ACE) is obtained by a teacher with a teaching diploma. Six (18.8%) teachers possessed teaching diplomas. Half of the teachers (16 teachers, that is 50%) who completed the questionnaire had an ACE qualification and 10 (31.2%) teachers had science degrees (see figure 5). A highly qualified teacher is more effective in teaching and his learners achieve better results (Rice 2003; Darling-Hammond, 2000).

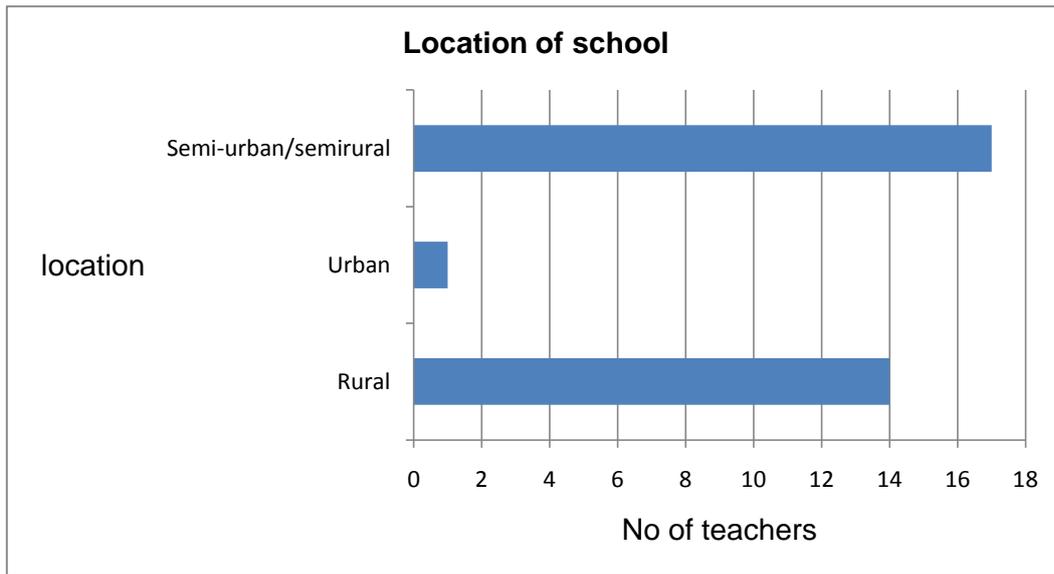
Figure 5: Teacher qualifications



4. Type of school where the teacher is working.

The geographical position of the school has an effect in the performance of the learners (Ma & Wilkins, 2002). In the sample of study it was observed that most schools in the rural and semi-urban areas did not have the necessary equipment and apparatus to carry out the activities (see paragraph 2.2 sub-section 2.2.5). The researcher had to bring in slinkies, ripple tanks and eye-droppers. The selected schools were from urban, semi-rural and rural areas. The majority of the teachers are in the semi-urban areas (figure 6).

Figure 6: The geographical location of the schools



A significant number of teachers (17) indicated that their understanding of the Doppler Effect was satisfactory, neither good nor very good. It was therefore interesting to check on the qualifications of these teachers who had problems on the topic by cross tabulating teachers' qualifications and their understanding of the Doppler Effect (Table 6).

Table 6: Cross tabulation: Teacher qualification and understanding Doppler

		Understanding the Doppler Effect formula				Total
		Fair	Satisfactory	Good	Very good	
Qualification	Diploma	1	5	0	0	6
	Ace	3	8	5	0	16
	Degree	0	4	3	3	10
Total		4	17	8	3	32

It was interesting to note that the understanding by the teachers of the Doppler Effect does not depend on qualifications; 4 teachers (see table 6) with degrees find their understanding of the topic satisfactory. Not even one teacher with diploma or ACE qualification rated his/her understanding of the topic as very good.

5. Total number of learners in grade 12 physical science classes

Schools with many learners are actually performing better than schools with few learners (Department of Education, 2011) despite what some teachers say “the smaller the class the better the results”. In the sample of study the mean class size was 57 learners and this is quite normal in this province. Grade 12 results for the year 2010 have shown that some schools with large classes can perform much better than some schools with a few learners as shown in table 6. Mbilwi and Thohoyandou secondary schools had 327 and 168 candidates (table 7) respectively who sat for their grade 12 final examinations in 2010. They all passed. In contrast, a school with only 3 learners had a zero percent pass rate. The schools in table 6 were chosen from Limpopo province, four from Vhembe district. One other school was chosen from a different district to show that what the results indicate was not only restricted to the Vhembe district.

Table 7: Comparison of learners` performance in selected schools

	District	School	Total no wrote	Total no passed	Pass %
Limpopo Province	Vhembe	Thohoyandou	168	168	100
		Mbilwi	327	327	100
		Haggai	24	10	41.7
	Baltimore	Boithuto	10	0	0
	Vhembe	Wilmary Christian	3	0	0

Content, support and teaching method(s)

The following 12 questions were asked to obtain information on the teachers.

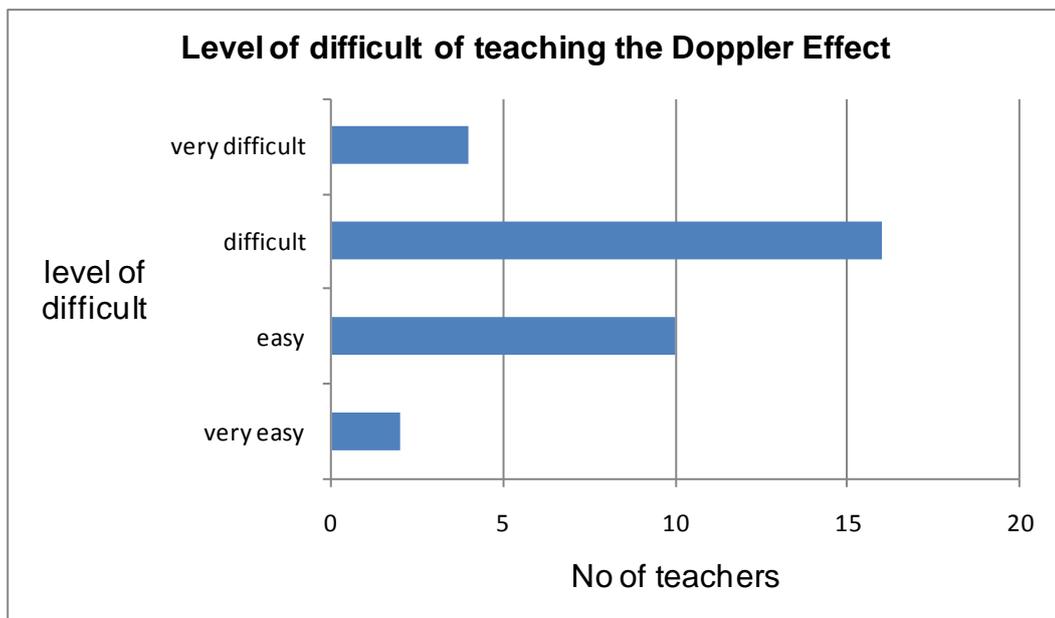
6. How do you rate the level of difficulty of teaching the topic Doppler Effect?

The topic Doppler Effect involves mathematical calculations which require learners to create mental visions of the situations being described in the questions (Trey & Khan, 2008). Angell et al., (2004) declared that Physics is a more conceptually demanding subject as compared to other disciplines. The teachers need to understand the content first before they could impart it to learners. As Wright and Wright (2000) have remarked- “one cannot teach, model or support what one does not know, feel or accept” (p.137). It is the role of the teacher “to model the appropriate mental processes so learners become aware of the correct mental procedures that will enable them to solve a problem” (NRC, 2005; Wenning, 2005).

Figure 7 shows that 16 teachers (50%) find the topic difficult to teach and 4 teachers (12.5%) find the topic very difficult to teach. This could indicate that the teachers` lack content knowledge of the subject and therefore they cannot be confident in teaching this subject.

Wilson & Floden, (2003) indicated that a teacher who has majored in physics is likely to perform better in that subject.

Figure 7: The teachers` assessment on the levels of difficult of teaching the Doppler Effect.

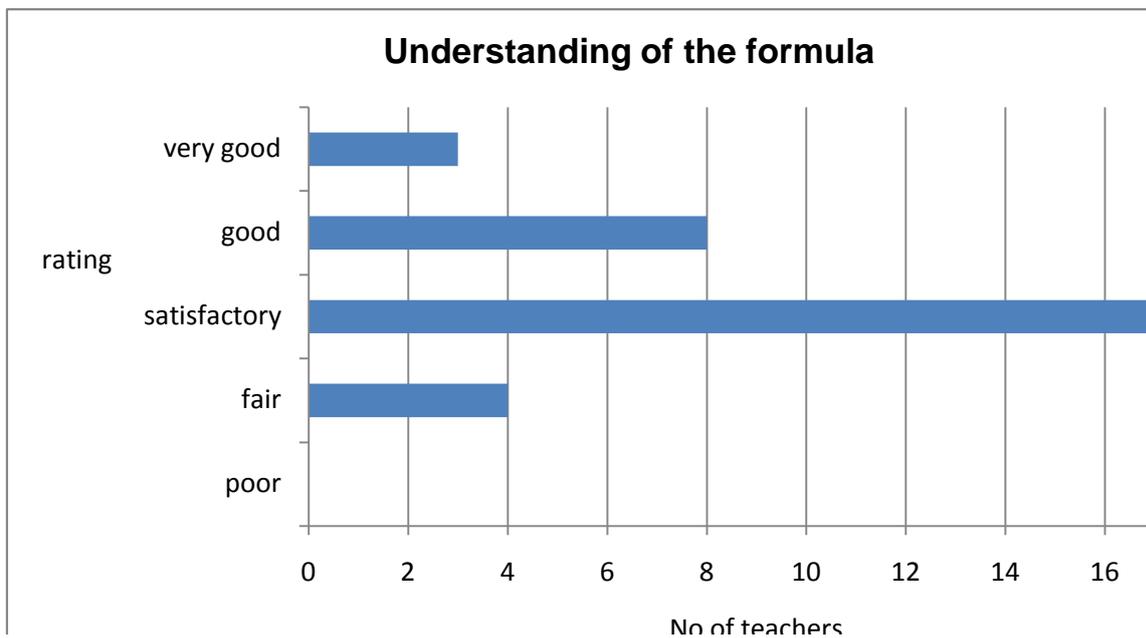


7. How do you rate your understanding of the formula?

$$f_i = \frac{v \pm v_i}{v \pm v_s} f_s$$

The teachers were asked to indicate, poor, fair, satisfactory, good and very good in the questionnaire. In question 6 the teachers find the topic difficult and it is not that surprising in question 7 when the majority of the teachers (53.1%) figure 8 rate their understanding of the formula as satisfactory.

Figure 8: Understanding of the formula by teachers.



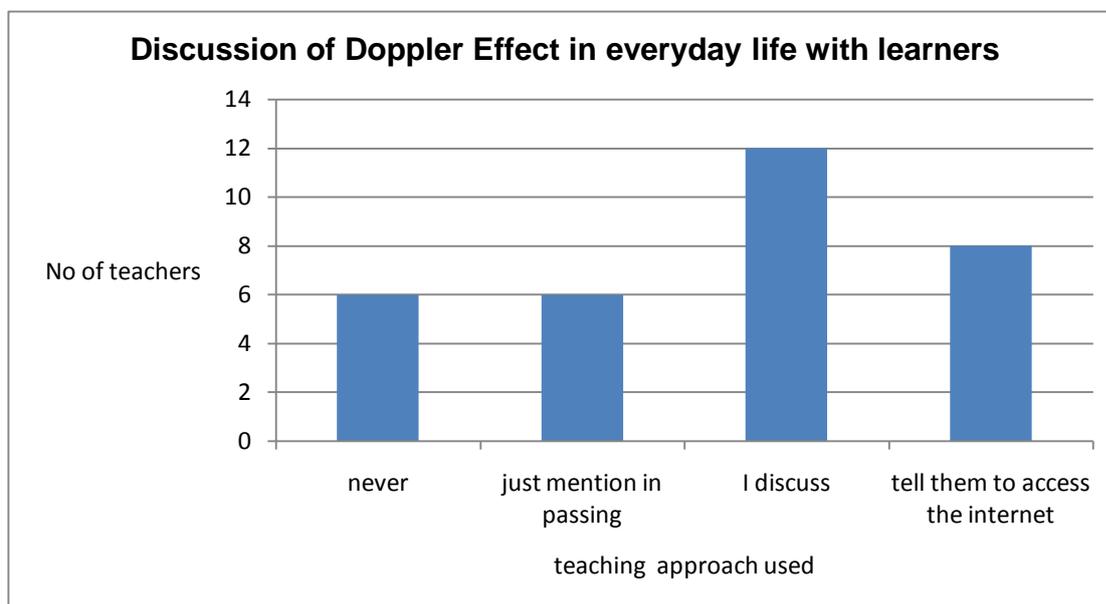
8. Do you discuss the application of Doppler Effect in everyday life with your learners?

Teachers had to choose from the following options: never, just mention in passing and I discuss and tell them to access the internet. This question was chosen to confirm whether teachers are complying with the learning outcomes or not. All the three learning outcomes emphasise that the learner should apply knowledge in everyday contexts.

Learners must be given the opportunity to experience science concepts through laboratory activities and they must link these concepts to their daily life experiences

(Park et al., 2008). From the analysis, 6 teachers (18.8%, see figure 9) have never discussed the application of Doppler Effect in everyday life with their learners.

Figure 9: Discussion of Doppler Effect in everyday life with learners



9. Under your given working conditions, which do you think is important when teaching the topic?

Teachers had to indicate, drilling learners, teach for understanding and rushing to finish the syllabus.

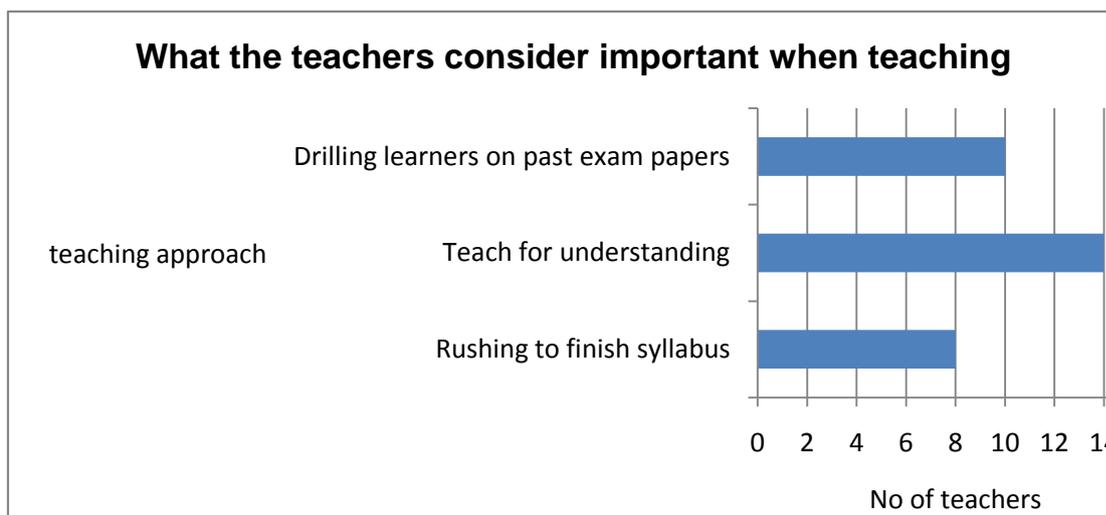
The study has revealed that 31.2% (figure 10) of the teachers drill learners on past examination papers, actually learners will be memorising terms, definitions and some answers to certain questions. This reveals a more traditional teaching style. The traditional teaching approach is in contradiction to the learner centred strategies outlined in paragraph 2.2 subsection 2.2.4. It is evident from the analysis of the results that those teachers (25%) who rush to finish the syllabus will not be using learner centred teaching practices. It is encouraging to note that 14 teachers (44.8%) taught for understanding and did not rush to finish the syllabus. According to the subject advisor (appendix 11 lines 32-36), *teachers should;*

“Use learner centred methods, not just talking and talking, learners need to participate, they must take part in the learning process, and science is a

practical subject. We would like teachers to carryout experiments to show learners the practical side of the theories”.

Those teachers who rush to finish the syllabus could possibly not be teaching for conceptual understanding.

Figure 10: What the teachers consider as important when teaching the Doppler Effect.



10. Have you ever been trained while you were still at college or university on the topic Doppler Effect?

N=32

Table 8: Teacher training on the Doppler Effect

Yes	14
No	18

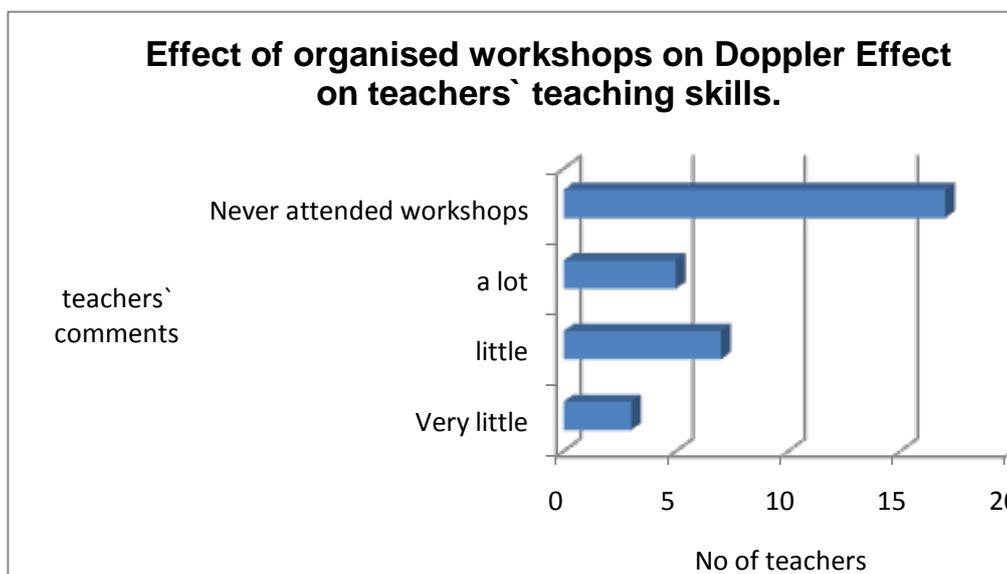
The issue of some teachers not understanding the topic (question 6 and 7) is now answered by the teacher responses to this question. If 18 teachers (56.3%) (see table 8), claim that they never did the topic at college or university and 53.1% teachers in question 11 never attended workshops (see paragraph 2.2 sub-section 2.2.2) on the topic Doppler Effect, then it is likely that they might not have the necessary content knowledge to teach the topic.

11. How have organised workshops on Doppler Effect enhanced your teaching skills on the topic?

Studies have shown that teachers gain professionally if they attend workshops and seminars where there is cross-pollination of ideas with other teachers and consultants (Loucks-Horsley, Hewson, Love, & Stiles, 1998). However, Ball, Lubienski, & Mewborn (2001) argued that workshops just update teachers' knowledge and do not provide platform for sustained learning on issues to do with learners, curriculum and teaching approaches.

From the information obtained, teachers (53.1%, figure 11) never attended any workshop on the topic and 9.4% claimed to have benefited very little from the workshops. This information points to the need for professional development for teachers.

Figure 11: The effect of organised workshops on teachers teaching skills.



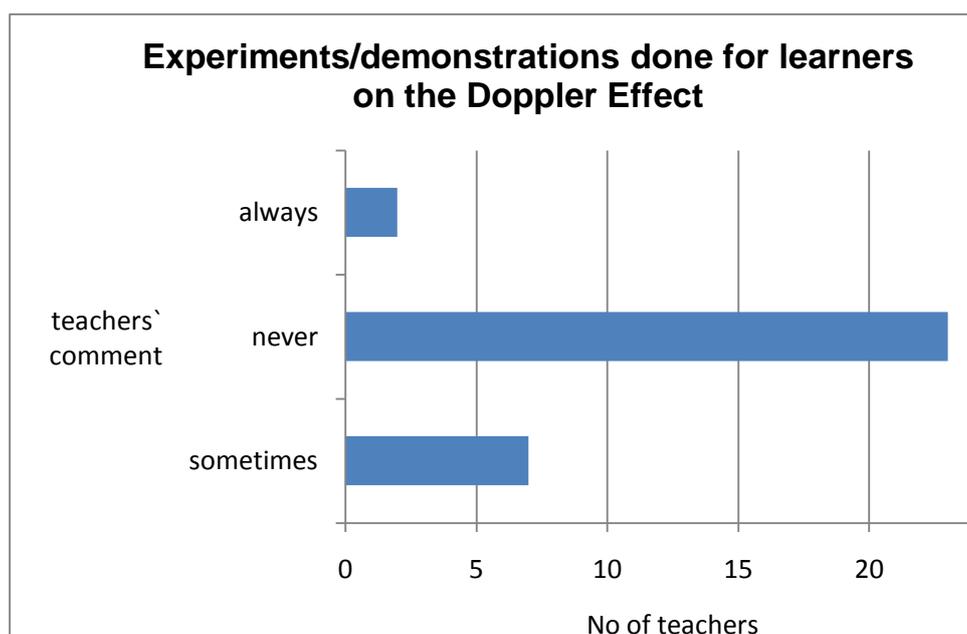
12. Have you ever done any experiment/demonstration for your learners on the Doppler Effect?

Studies indicated in the literature review (see paragraph 2.2) have shown that learners understand better when they do activities, observe phenomena and

draw their own conclusions. The learning outcomes stated in the NCS (DOE, 2003) require that learners should be able to interpret and evaluate scientific and technological knowledge and apply it to their daily lives. Science is a practical subject and learners tend to understand the concepts better if they carry out experiments which are relevant to the topic (Berenfeld et al., 2004). According to Kimbrough (1995, p 172) learners perform better and develop positive attitudes towards science when they perform practicals.

In this study, 71.9% (figure 12) of the teachers never did any demonstration/ experiment when teaching the topic Doppler Effect. Only 6.3% claim to always do demonstrations/experiments when teaching the topic.

Figure 12: Experiments/demonstrations done for learners on the Doppler Effect.



13. Do you have access to computers to teach the topic?

In this modern world the use of computers has improved the teaching and learning in schools. Students were found to achieve better in science after the instruction using simulations and computer-aided-instruction (CAI), (Trey & Khan, 2008). Also, a meta-analysis of effectiveness of CAI proved that learners can

improve their performance in science (Bayraktar, 2001). Therefore, teachers should make use of simulations in their lessons to enhance learner's understanding as the mentioned studies have shown.

However, the disadvantage of computer simulations is that learners do not get real laboratory experience of handling the apparatus (Corter, Nickerson, Esche, Chassapis, Im, & Ma, 2007). There has been an increased access to ICT in the educational environment in other countries (Hartley, Treagust, & Ogunniyi, 2007). In order for the learners to have a better understanding of the science concepts, the teachers should teach using methods that combine modelling and visualisation as opposed to traditional teaching practices (Gilbert *et al.*, 2003).

The majority of the teachers (65.6%) (See table 9) have no access to a computer laboratory, no access to internet, do not own personal computers and only 34.4% do have access.

N=32

Table 9: Teachers' access to computers.

	Total no of teachers
Yes	11
No	21

14. Are you using the computer to teach the Doppler Effect?

Although 11 of the 32 teachers (34.4%) (Table 8) do have access to computers only 6 (18.75%) (Table 10) use a computer to teach the topic. Some of those who use computers to teach the topic do so by showing learners the simulations and the diagrams illustrating the Doppler Effect.

N=32

Table 10: Teachers` use of computers.

	Total no of teachers
Yes	6
No	26

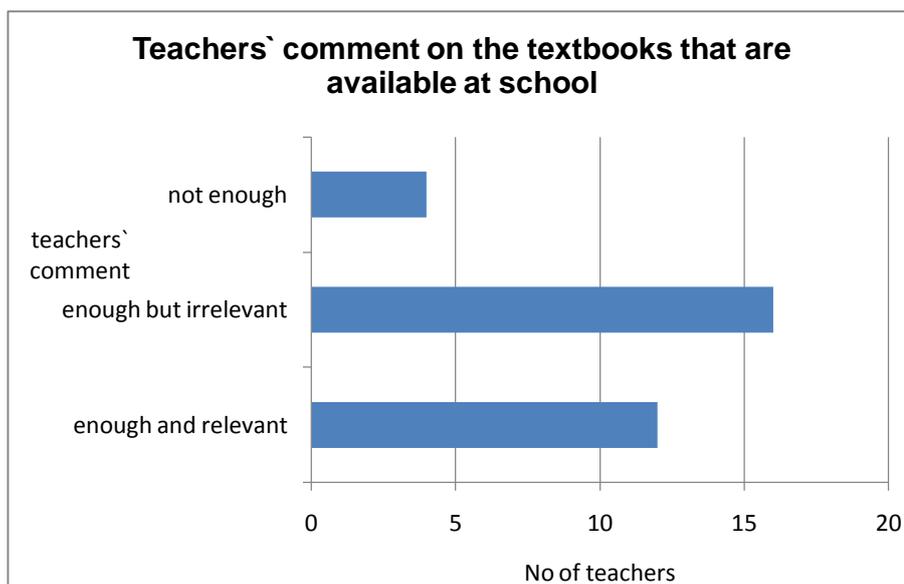
This is an alarming situation because according to Choi & Park (2003) computer simulations simplify difficult experiments which are carried out in laboratories. This study revealed that 81.3% (table 9) of the teachers do not use computers to teach. Computer simulations generate high level of involvement; learners explore and understand more regardless of their experience (Perkins & Wienman, 2006). Jimoyiannis and Komis (2001) found that computer simulations are very effective in the teaching and learning of physics. In this study, computer simulations were not used by learners as part of the activities and are acknowledged as a limitation of the study. The use of simulations to demonstrate the Doppler Effect phenomena have therefore been suggested for future studies.

15. How would you comment on the text books that you have?

Science learning is conducted through the use of textbooks and this is considered as a requirement for the production of scientists (Klassen, 2006). In addition to that textbooks contain information and activities needed to acquire the desired learning outcomes (Khutorskoi, 2006). Furthermore studies have revealed that textbooks are used globally (Lemmer, Edwards, & Rapule, 2008; Stern & Roseman, 2001).

A significant number of teachers 37.5% (figure 13); do not have the required textbooks. It is shown that 50% of the science text books in the schools are irrelevant with regards to the content. Only 12 teachers indicated that they have enough and relevant text books.

Figure 13: Teachers` comments on the textbooks that are available at school



16. Briefly describe how you would teach the topic Doppler Effect?

Table 11: Teaching approaches

Teaching approach categories	Total no of teachers	%
Explain, give notes, define terms	21	65.6
Explain, give notes, do practicals/ demonstrations	2	6.3
Explain, give notes, work out problems, discuss applications	8	25.0
No idea	1	3.1

It is during science activities that learners have a unique experience, they open up to new ways of learning (White, 1996). Research studies revealed that teaching practices which offer learners high opportunity to learn using experiments are related to better learner performance (Grouws, & Cebulla, 2000; Ingvarson et al., 2004).

From the information in the table 11, it is clear that the majority of the teachers (65.6 %) use traditional teaching approach, where they give explanations, notes and define terms.

17. How would you know the learners understood the Doppler Effect?

Table 12: How the teacher evaluates learners on the topic.

Assessment categories	Total no of teachers	%
Giving tests, class work, homework	21	65.6
Asking of questions during lesson	5	15.6
Application of knowledge, discussions, correctly solved problems	6	18.8

Assessment of learners can be either summative or formative. Teachers do summative assessment when they gather evidence systematically and in a planned way so as to draw inferences about the learner's learning, based on their professional judgements and to report at given times on learners achievement (Garet, Porter, Desimone, Birman, & Yoon, 2001). Formative assessment is when teachers and learners are involved to improve learning. This involves the assessment of progress and analysing it, so as to improve the learner and for the teacher to adopt effective teaching approaches to address identified needs (Borich, 1996).

Teachers were required to indicate the methods they use to assess their learners from choices given in the questionnaire. In order to evaluate the learners' understanding of the Doppler Effect 65.6% (table 12) of the teachers give tests, class work and homework. Only 15.6% ask oral questions during the lesson to check on the understanding of the learners.

18. Comment on the availability of science apparatus and equipment at your school.

Table 13: Teachers` comments on availability of science equipment in their schools.

categories	Total no of teachers	%
No equipment/apparatus	23	71.8
Few, not enough	4	12.5
Enough equipment/apparatus	0	0
Available but irrelevant to the topic	5	15.6

Schools in rural areas have a shortage of science apparatus (Sadler& Tai, 2001), and this is the case in some Vhembe rural schools. A large number of teachers (71.8%) (Table 13) have indicated that their schools have no equipment/ apparatus to use during science lessons. Despite the government`s claims of equipping schools with science equipment (see question 4, paragraph 4.2) 23 teachers indicated that they do not have science equipment at their schools. Greenwald, Hedges, & Laine, (1996) in their study has revealed a relationship between school resources (equipment) and learner achievement. The same study also points out that a learner with resources performs better in the examinations. Not even a single school in this sample has sufficient equipment. The schools located in poor rural areas do not have enough equipment and they might not have a teacher exclusively teaching Physics (Sadler & Tai, 2001). In this study, there were only 2 out of a total of 10 teachers with degrees who are working in the rural areas (see appendix 15, table 16).

According to the Department of Education, all schools have been provided with equipment to do practical work (Strategic Plan 2007-2011). The then Minister of Education Mrs Naledi Pandor said;

The sector (DOE) will receive more resources and relevant support to ensure that all schools offer quality teaching and learning in mathematics and science by qualified teachers. Schools will be provided with adequate resources and facilities to enable them to successfully teach these subjects.

However, according to this limited study it does not seem the case.

4.3 Phase 1: Results and analysis of interview with the subject advisor

The subject advisor gave his responses which were transcribed (see appendix 11). According to the subject advisor the challenges teachers experience in their practice in the teaching of the Doppler Effect are:

- i) Teachers lack content knowledge (see appendix 11 line 11) and that they are under qualified to teach the subject.
- ii) Calculations on the Doppler Effect and the use of the formula (line 23) and also linking the theory with the practical real life situations for the learners to understand (lines 24 and 25).
- iii) Schools lack the necessary equipment to carry out the experiments during lessons, the subject advisor said that; “we are aware that not all schools have science equipment” (appendix 11 lines 36-37). In some cases the teacher is left with no choice but to teach without performing any experiments or demonstrations.

It can therefore be claimed that some of the challenges in teaching the Doppler Effect are lack of teacher content knowledge and ineffective teaching approaches (see paragraph 2.2 subsections 2.2.3 and 2.2.4).

4.4 Phase 2: Results and analysis of activity sheets and test

The usual time allocated to the teaching of the Doppler Effect is five lessons of 270 minutes (4 x 60 minutes plus one single lesson of 30 minutes). The activities developed were tried out during two double lessons. The first lesson was a practical lesson; learners were completing activity sheets (appendices 4, 5 and 6) as they

carried out the activities. The completed activity sheets were marked to quantify the effectiveness of this teaching strategy. The marks were expressed in percentages.

The study used the theoretical framework (see paragraph 2.6) as a lens to look at the development of EDR activities and how the practical links with the theory (tables 14 and 15). The “phenomenographic component” (description of the Doppler Effect phenomena and lack of understanding of the concept) has led to the development of “model” or EDR activities which were used in schools by learners which in turn led to the “phenomenotechnic component” (knowledge of laboratory equipment and development of practical skills).

In the second lesson learners were given a written test (appendix 12) on the Doppler Effect in which they were required to solve mathematical problems involving the Doppler Effect formula. The LO1 (paragraph 1.1) requires that learners should solve problems in a scientific, technological and everyday contexts. The given questions were typical of final examination questions in order for the learners to be familiar with the questions to ensure that learners have appropriate practice before they write their final examinations. The answers were marked out of 100. The analysis of the results for the 2 trial schools were recorded (see table 14).

Table 14: Comparison on the learners` performance, in set activities and written test in 2 schools.

Mark range	Design based activities		Written test	
	No of learners		No of learners	
	School 1	School 2	School 1	School 2
90-100	0	0	0	0
80-89	1	1	0	0
70-79	1	3	0	1
60-69	3	4	1	1

50-59	4	3	1	4
40-49	5	3	3	7
30-39	2	5	7	3
20-29	2	3	3	5
10-19	0	1	2	1
0-9	0	0	1	1
	18	23	18	23
% of learners who got marks above 30	88.9	82.6	66.7	69.6

The results in table 14 show that learners in both schools performed better in questions on activities (88.9% and 82.6%) than on the written test (66.7% and 69.6%). A possible reason for this result is that learners understand better and perform better when they practically do the activity (Nui & Wahome, 2005). The two teachers of these learners were from an urban school and a rural school and both had more than 10 years experience with ACE diplomas.

Below are the changes made to the activities by changing the phrasing of questions for clarity and to the type and usage of equipment in favour of those that were available to teachers.

- a) Cafeteria trays were replaced by ripple tanks for better observation of created waves.
- b) The eyedroppers were replaced by small plastic pipettes which were able to produce constant supply of droplets at a faster rate.
- c) Some schools were supplied with plastic pipettes, slinky, ripple tanks by the researcher since they did not have them.

- d) For the bicycle experiment, cell phones were used to supply a source of sound since some schools did not have portable sirens.

Phase 3

The changes were implemented and the activities were tried in 10 schools. Teachers were visited and consulted to ensure that the teachers in the schools were on the same level in terms of teaching the Doppler Effect. The activities and what was expected from them were clearly spelt out.

Table 15 show the results of the two marked activities for 10 schools with a total of 216 learners. The comparison was mainly on the learners` performance in the set activities and written test and not on individual schools. The purpose of the comparison was to establish a correlation between these two activities and to find out in which of the two activities learners performed better. This was done to prove on whether learners perform better on practical questions or on theoretical questions. There was a discrepancy between the mean EDR activity scores and written test scores and this might be due to:

- Learners understand more when they do hands-on experiments whilst making their own observations than in tests where they are required to do problem solving and interpret the phenomenon.
- During lesson activities learners share ideas whereas during tests they are expected to work on their own.

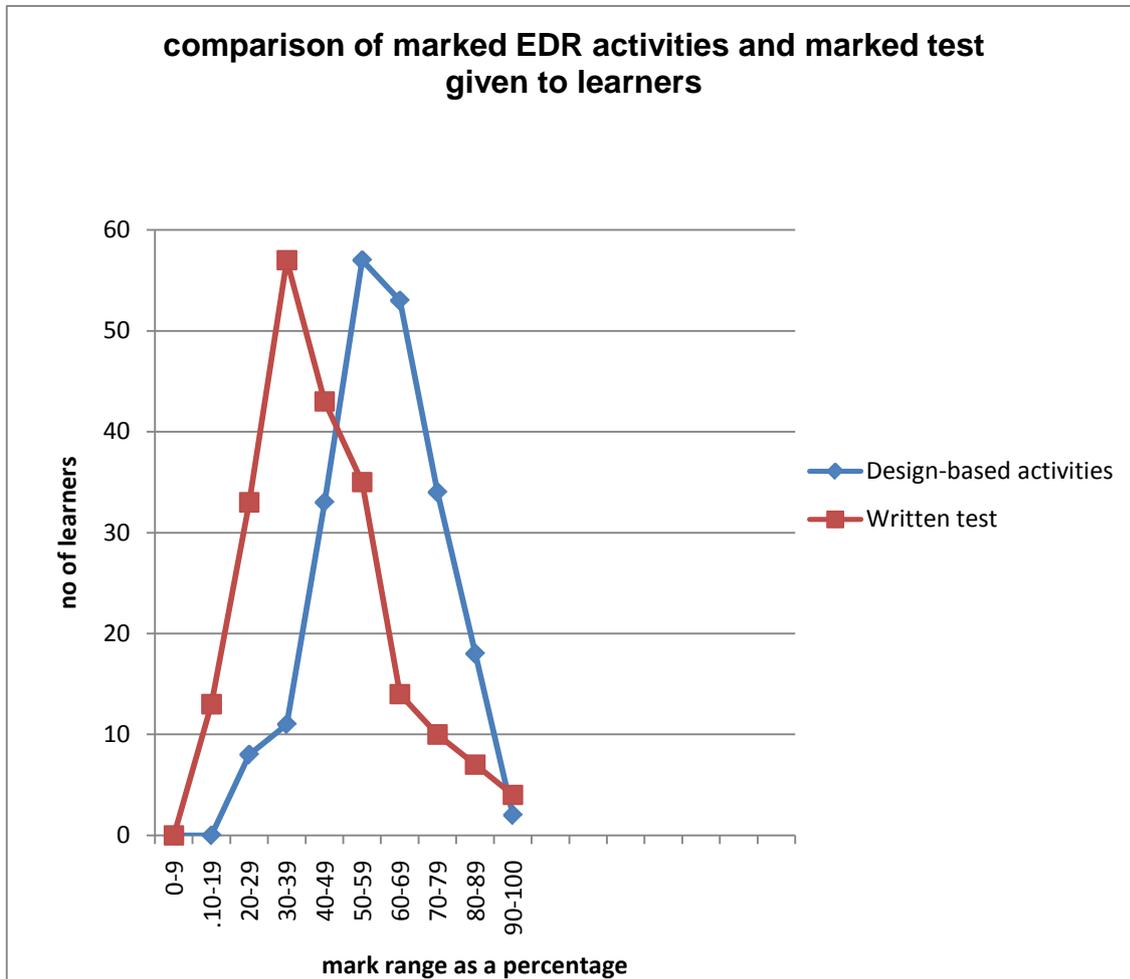
Table 15: Graphical comparison on the performance of learners on EDR activities and problem solving in 10 schools (N=216).

Mark range	EDR activities		Problem solving	
	Total learners	%	Total learners	%
90-100	2	0.9	4	1.9
80-89	18	8.3	7	3.2

70-79	34	15.7	10	4.6
60-69	53	24.5	14	6.4
50-59	57	26.4	35	16.1
40-49	33	15.3	43	19.9
30-39	11	5.2	57	26.5
20-29	8	3.7	33	15.3
10-19	0	0	13	6.0
0-9	0	0	0	0
	216	100	216	100
% No of learners with marks 40% and above	91.2%		47.7%	

Results on table 15 show that learners performed well in the EDR activities with 91.2% of the learners scoring marks above 40% and in written tests only 47.7% of the learners scored above 40% mark. This might indicate (among other possible factors) that learners understand more what they do (practically) than the solving of theoretical problems.

Figure 14: Comparison of marked EDR activities and marked test given to learners (N=216).



Pearson's product moment Correlation $r = 0.65$ (see appendix 13) indicates a high correlation (Mulder, 1993) between student EDR activities and the written tests. These results are supported by the subject advisor (appendix 11, line 42) that learners will understand more what they see and do. They performed poorly in their tests compared to the activities and this might be due to the poor understanding of the formula and concepts (appendix 11, line 23). Also the teachers themselves were partly to blame because only 9.4% (see paragraph 4.2) of the teachers can interpret the Doppler Effect formula.

4.5 Phase 3: Results and analysis of learner and teacher interviews

After the activity based lesson, some of the learners and the teachers were randomly selected for interviews for the purposes of evaluating the lessons, based on the geographical position of the school (urban, semi-rural and rural). Three teachers and three learners were interviewed from different schools. The results of the analysis of responses are not generalised because only 3 out of 216 learners were interviewed.

Teachers' question: What is your opinion on the lesson?

The following were the responses given by the teachers. Some of the statements were made in Tshivenda language, the English translation is in brackets.

Teacher A:

The lesson was good, learners enjoyed a lot, and even my usually sleeping friends (learners) were awake today.

Teacher B:

It was nice it makes teaching much easier mara (but) you cannot do this all the time, look, we don't have apparatus here also zwia dzhia tshifhinga u lugisela (it takes a lot of time to prepare) but it's very good.

Teacher C:

I have never seen my learners so happy, we have seen these things first time today, ripple tanks, spring and all that, the topic becomes easy, but I have many learners the syllabus is long you know, on top of that we don't have these apparatus, if I do this every day I will not finish the syllabus.

The three learners interviewed were from rural, semi-rural and urban areas.

Learners' question: How was the lesson?

Learner X:

Yovha i ya vhudi nga maanda, arali ri tshi khou guda nga heyi ndila, ngoho ri do pfasa. (The lesson was very good, if we were to continue learning in this way, truly we will pass).

Learner Y:

Our teacher does not use your (referring to researcher) things, he teaches and teaches, zwi songo pfara, zwitshi khou konda, mara today ndo zwipfesesa. (our teacher does not use your equipment, it was difficult to understand, but today I understood).

Learner Z:

Yova ya vhudi badi. Zwi khou pfara arali ri tshi khou shumisa hezwi zwithu (it was very good. It is easier to understand when we use these apparatus) it was ok, very ok.

In summary the teachers enjoyed the activities but they had the following concerns:

- The activities take a lot of time to prepare; they might not finish the syllabus.
- They do not have the apparatus.

The demand to increase pass rate from the Department of Education (see paragraph 2.2.4) has led teachers to use traditional teaching approaches which could possibly not be beneficial to learners. Learners will understand more when they use activities during their lessons, (Park et al., (2008); Berenfeld et al., (2004) and Kimbrough (1995)).

The learners said that it was easier to understand the topic when using EDR activities. The reason why they performed badly in tests might be that learners have some difficulties with understanding the concepts (Thornton & Sokoloff, 1998). The fact that teachers indicated that they did not understand the Doppler Effect formula (see paragraph 4.2 question 7) implies that their content knowledge is questionable and that their lesson might not have been effective.

4.6 Summary of findings

According to the research methodology (paragraph 3.5) this study was done in three phases. Phase 1 was the establishment of the baseline using a questionnaire with 18 questions which was completed by the teachers and an interview conducted with the subject advisor. In phase 2, activities were developed and tried out in 2 schools. Finally in phase 3, the redeveloped activities were tried out in 10 schools in which learners completed activity sheets and wrote a test and both were marked and

analysed. Interviews were conducted with 3 learners but because the sample is too small no inferences/conclusions could be made from these interviews.

Therefore in order to answer the first research question namely;

1. Which aspects of the topic Doppler Effect do the teachers find challenging?
 - a) What are the challenges that the teachers have in terms of content delivery?
 - b) Which teaching methods do teachers use when delivering lessons on the Doppler Effect?

Data collected from the teachers' questionnaire, interview with the subject advisor, was analysed. From the teacher's questionnaire the following information is highlighted:

The majority of teachers (50%) have an ACE teaching qualification (See appendix 15 table 16). This could be a problem regarding teachers' lack of content knowledge and has been reflected by teachers' lack of confidence in teaching the Doppler Effect. The total percentage of teachers who find the topic Doppler Effect difficult and very difficult is 62.5%. This could explain why learners also perform badly in this topic (paragraph 4.2 question 6). When teachers were asked how they would rank their understanding of the formula describing the Doppler Effect 53.1% indicated only a "satisfactory" and only 9.4% understood and could interpret the formula.

In terms of professional development, little assistance is given to teachers. A total of 53.1% of the teachers have never attended any workshop on Doppler Effect and 9.4% who attended indicated that they benefited very little from the workshop.

Physics is a practical subject and it has to be taught as such, the study revealed that 71.9% have never done any experiments or demonstrations on the Doppler Effect.

On the issue of textbooks, 50% teachers indicate that there are enough books but irrelevant in the sense that they do not have information on the Doppler Effect. Studies (paragraph 4.2 question 15) have shown the importance of textbooks to learners.

The teacher needs to transform the knowledge of the content into a structure that the learners can understand (Shulman, 1986) by using effective teaching approaches. On teaching approaches, 65.6% gave explanations, definition of terms and notes to

learners. A significant number (18.8%) of teachers were not linking the concepts to learners' everyday experiences. The data reveal that there is limited teaching for understanding because 25% of the teachers indicated that they rush to finish the syllabus and 31.2% concentrated on drilling the learners on past examination papers.

Only 6.3% do demonstrations apart from giving notes and explanations. The cause of not doing demonstration/practicals might be that of lack of apparatus and equipment, since 71.8% said they don't have apparatus/equipment at all.

Interviewing involved asking of questions orally to respondents and its limitation was the small sample. An interview was conducted with the subject advisor who also pointed to the lack of content knowledge of the teachers (appendix 11 lines 11, 16, 17 and 27) and lack of science equipment in schools (appendix 11 lines 36-38) as factors contributing to the poor performance of learners in the examinations.

The second research question was;

What is the effectiveness of teaching the Doppler effect using developed learner-centred activities?

The developed activities were effective; the learners enjoyed the lessons and performed well in the marked activities. This finding confirmed the findings of other researchers (Berenfeld et al., 2004; Ingvarson et al., 2004; Kimbrough, 1995).

The data collected from 216 learners indicated that only 8 (3.7%) learners got below 30% when activity sheets were marked. Whereas when tests results were analysed 46 (21.3%) learners got below 30% pass mark (paragraph 4.4 table 14). The better performance of learners in the activities indicated to an extent their effectiveness. When interviewed after the lesson in which learners used EDR activities (paragraph 4.5), all 3 learners said they enjoyed the lesson and that they understood the concepts more when they used the equipment to do the demonstrations. However, there was still a problem that the learners could not answer all questions in the written tests correctly as good as they did on the practical activities (Angell et al., 2004; Trey & Khan, 2008). The possible reason might be that they did not understand the topic.

4.7 Summary

This chapter presented the results and the analysis of the questionnaire for teachers, interview with the subject advisor and activity sheets and test. Finally, a summary of the findings was done.

4.8 Projection for the next chapter

The implications of the analysis of the results and findings will be discussed in the next chapter. Conclusions and recommendations for further study are also presented.

CHAPTER 5: DISCUSSIONS AND CONCLUSIONS

5.1 Introduction

This chapter presents answers to the research questions and provides a summary, conclusions and discussions. The chapter ends by giving some recommendations and concluding remarks.

5.2 Summary

Teaching of Science

Science education need to be improved by the science community to make it effective and relevant, improving science education would produce more scientists and engineers (Wieman & Perkins, 2005). The teachers are the key contributors to the transformation of education and they are expected to be qualified, competent, dedicated and caring for their learners (Department of Education, 2003).

A teacher needs amongst others:

- Content knowledge which consists of mental representation of ideas that the teacher has constructed on the subject (van de Walle, 2004). Lack of content knowledge by the teacher will hinder his/her effectiveness and competitiveness (see paragraph 2.2 sub section 2.2.3). The teachers who took part in the study had the following qualifications; 6 with diplomas, 16 ACE qualification and 10 had science degrees. However, 20 teachers found the topic Doppler Effect difficult (and very difficult) to teach (paragraph 4.2, question 6). In addition, 17 teachers rated their understanding of the formula as satisfactory and only three teachers said that their understanding of the formula was very good (paragraph 4.2, question 7). Therefore, the majority of the teachers lacked content knowledge of the subject.
- Teaching approaches: It is important for a teacher to have a variety of teaching approaches depending on what the teacher wants to achieve. The study revealed that teachers were not using learner centred teaching approaches, 8 teachers would rather rush to finish the syllabus and 10 teachers would drill the learners on past examination papers. Of serious

concern is that 23 teachers (see paragraph 4.2 question 12) indicated that they have never done any experiment or demonstration on the Doppler Effect with their learners. Doing activities contributes to a learner centred lesson.

- Curriculum: The Department of Education in every country describe their curriculum. The curriculum in South Africa has changed several times and the NCS curriculum had its first examination written in 2008. The activities set in this study are in support of the LO's of the physical science as set out by the Department of Education, (2003). Both the NCS curriculum and OBE approach, point to the importance of a learner centred approach.
- Professional development: In Vhembe District teachers are encouraged to enrol for further studies. According to the subject advisor the DOE is having logistical challenges in organising and executing effective workshops for teachers (see appendix 11 lines 46-48).
- Resources: Textbooks and science equipment are necessary for the effective learning of science (see paragraph 4.2 questions 15 and 18). In Vhembe the situation is bad; 16 teachers say the textbooks are there but not relevant with regards to the Doppler Effect. Equally bad is the fact that 23 teachers out of 32 teachers indicate that they do not have science equipment at all. As a result, this study has contributed to development of activities for use in schools so that learners are actively involved in the learning process.

EDR Activities

The activities were developed to integrate content knowledge, learner centred approach and all LOs. The use of apparatus that are not expensive yet readily available was incorporated. The activities were tried out in 2 schools and the refined activities were then tried out in 10 schools. Learners performed well and this was reflected in the presentation of their achievement in the marked activity sheets.

Results of the analysis of the questionnaire have revealed the teaching approaches which some teachers used. Some teachers are still using the traditional teaching methods and are neglecting the three physical science learning outcomes. The study has revealed that the learners understand more and perform actively when the lesson is taught using EDR activities. There is a direct correlation between EDR

activities and solving of problems on the topic Doppler Effect. Those learners who did well in practical activities also did well in the test. However, the learners scored high marks in EDR activities indicating that the topic can be understood more when learners actively participate in the learning process. The teachers lack the content knowledge of the topic and they found the topic difficult to teach.

The theoretical framework guiding the study was formulated in chapter two which enabled the researcher to keep focused on the link between the theory and the developed EDR activities.

As regards the empirical referent, the learners were able to manipulate apparatus, which meant they possessed the phenomenotechnic component (experimental ability). What learners require is science equipment and clear instructions to guide them. Learners confirmed that they understood better the Doppler Effect phenomena when they carried out the activities (i.e. the phenomenological component). They were able to explain, describe and interpret the Doppler Effect phenomenon (i.e. the interpretive elaboration). What was encouraging was that learners were able to explain the meaning of the symbols in the Doppler Effect formula and to draw diagrams representing sound waves. Finally, the learners were able to merge the theory and experimental knowledge in constructing their knowledge (cognitive matrix).

5.3 Conclusions

Content knowledge:

A significant number of teachers find the topic Doppler Effect difficult to teach. The Subject Advisor also indicated that teachers do lack content knowledge of the topic. As a result the teachers rush to finish the syllabus and some resort to drilling the learners on past examination papers.

This topic was not dealt with by some of the teachers in their initial training at Colleges. The majority of teachers have never attended any workshops on the Doppler Effect in this district. Those who attended the workshop indicated that they benefited very little. According to the subject advisor there have been challenges such as time and resources in organising workshops on the topic to assist the teachers.

Teaching approach:

The findings indicate that the teachers do not use learner centred approaches. The majority of the teachers fail to do class demonstrations/practical activities citing lack of apparatus as the main cause. The findings show that the teachers have never done any experiment/demonstrations when teaching the Doppler Effect. A significant number of teachers never discuss applications of the Doppler Effect in everyday life with their learners.

Activities and written tests:

The performance of learners in the given developed activities was good (see paragraph 4.4 table 14). The learners were actively participating in the learning process (paragraph 4.5) as seen by the fact that they all participated in the activities and completed the activity sheets. The learners were empowered with the learning outcomes (see paragraph 1.1) in physical science. There is a high correlation ($r = 0.65$) between activities and the written tests. Some learners who did well in activity questions also performed well in solving of problems on the Doppler Effect.

5.4 Discussion

The study investigated the challenges and prospects of teachers when teaching the Doppler Effect to grade 12 learners. Challenges such as lack of content knowledge and hence confidence in teaching the topic were prevalent. The majority of the teachers were in need of professional development in order to acquire the needed skills, content knowledge and effective teaching approaches. In addition the teachers faced the challenge of the lack of science laboratories, science equipment and textbooks.

Prospects in teaching the Doppler Effect by means of the developed activities seem to be effective. Teachers were provided with handouts that supplied them with the necessary content knowledge as well as introducing learner centred activities. The learners enjoyed the activities and they understood the concepts better (see paragraph 4.6) when they observed demonstrations and actually handled the apparatus doing the experiment by themselves (Grouws, & Cebulla, 2000; Ingvarson et al., 2004).

5.5 Recommendations

1. Recommendations for practice: Implications for teaching and learning.

Professional development programmes should enhance teachers' content knowledge. Science is dynamic and therefore teachers use new effective teaching approaches. According to this study the professional development with regards to workshops was not effective in the Vhembe district. This agrees with earlier findings by Little & McLaughlin (1993) that professional development for teachers was not effective. Professional development programmes should include teaching activities in their lessons for better understanding of the science concepts by the learners and engage learners' hands on and minds on during the lessons. In addition, teachers need to teach for understanding and opportunities should be offered for lifelong learning experiences.

2. Recommendations for the design of learner activities

To facilitate conceptual understanding the activities should be designed making use of materials which are readily available within learners' environment. The physical phenomenon being studied should be linked to the learners' everyday experiences and examples to be drawn from what they observe in the area in which they live.

3. Recommendations for further research

This study recommends that future researchers should use a bigger sample of teachers and learners. During the development of the design-based activities, teachers should be involved so as to instil a sense of ownership in them. The activities are not to be imposed on them but produced by the teachers themselves. Also when designing learner activities the researcher should take into consideration the science equipment available in targeted schools. Most secondary schools in Vhembe district have computers therefore; this study recommends computer simulations on the Doppler Effect to be used together with hands on practical experiments.

5.6 Concluding words

This study is the first of its kind in the selected district in the Limpopo province. Therefore, in order to make a meaningful contribution to the community, an instructional manual on the Doppler Effect has been produced. This study has also proved that a laboratory is not a requirement to conduct experiments on the Doppler Effect. Moreover, the learners understood more by using the materials in their environment and their everyday experiences.

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APPENDICES

Appendix 1: Questionnaire for Teachers

Sure Mupezeni is a student at UNISA and conducting a research in the Thohoyandou Cluster in Limpopo Province in the Vhembe district on *Challenges and Prospects of teaching Doppler Effect in grade 12*. The findings of this research may assist Curriculum Advisors, Examiners, Subject Advisors and teachers. You are kindly requested to answer all questions to the best of your ability and sincerity. Please note that your responses are going to be treated with strict confidentiality and that answering these questions is not obligatory. Contact no.0847838451.

Personal Information

1. Gender

Female	
Male	

2. Science teaching experience in years

0-5	
6-10	
11-15	
16-20	
Above 20	

3. Indicate your qualifications

Diploma	
---------	--

ACE	
Degree	

4. Location of the school where you are teaching

Rural	
Urban	
Semi-urban/semi-rural	

5. Total number of learners in your grade 12 physical science class

Content, support and teaching method(s)

Tick the appropriate box

6. How do you rate the level of difficulty of teaching the topic Doppler effect?

Very easy	
Easy	
Difficult	
Very difficult	

7. How do you rate your understanding of the formula

$$f_k = \frac{v \pm v_l}{v \pm v_s} f_s$$

Poor	
fair	
Satisfactory	
Good	
Very good	

8. Do you discuss the application of Doppler Effect in everyday life with your learners?

Never	
Just mention in passing	
I Discuss	
Tell them to access the internet	
Tell them to read their textbooks	

9. Under your given working conditions which do you think is important

Rushing to finish the syllabus	
Teaching at the rate at which learners understand	

Drilling learners on past examination papers	
--	--

10. Have you ever been trained while you were still at college or university on the topic Doppler Effect?

Yes	
No	

11. How have organised workshops on Doppler effect enhanced your teaching skills on the topic ?

Very little	
Little	
A lot	
I have never attended a workshop on the Doppler effect	

12. Have you ever done an experiment/demonstration for your learners on the Doppler Effect?

Sometimes	
Never	
Always	

13. Do you have access to computers to teach the topic?

Yes	
No	

14. Are you using the computer to teach the topic?

Yes	
No	

15. How would you comment on the text books that you have with regards to Doppler Effect?

Not enough	
Enough but irrelevant	
Enough and relevant	

16. Briefly describe how you would teach the topic Doppler Effect?

.....
.....
.....

17. How would you know the learners understand the Doppler Effect?

.....
.....
.....

18. Comment on the availability of science apparatus and equipment at your school

.....
.....
.....

Appendix 2: Interview schedule: Physical Science Subject Advisor

- ✓ Greetings and Introductions
- ✓ Purpose of the interview stress that all responses are going to be treated with utmost confidentiality.
- ✓ Expected outcomes of the study

1. Sir, for how long have you been a Science subject Advisor?
2. May you comment on the learners `performance in NSC final examinations in Physical Science?
3. According to your opinion what might be the causes of such performance by the learners?
4. Please comment on teacher qualifications and experience in the subject in your district?
5. What are the teachers' main concerns regarding the topic Doppler Effect?
6. What do you consider as main challenges regarding the topic Doppler Effect?
7. Which method(s) are the teachers using when teaching this topic?
8. Which method would you suggest to be most effective when teaching this topic Doppler Effect?
9. What guidance or support is available to teachers to help them with the topic?
10. Any observations regarding the teaching of Doppler Effect that you have made over the years, which you might want to share?

Thank the interviewee and promise to share with him/her the findings of the research.

Appendix 3: Lesson on Doppler Effect

Lesson 1

Topic: The Doppler Effect.

Duration of lesson: 2 class periods (1 hour)

Lesson objectives

- i. Learners should be able to list the factors which affect the wavelength of a wave.
- ii. Learners should be able to explain the relationship between wavelength and frequency.
- iii. Learners should be able to explain what the Doppler Effect is.

Materials needed

- i. Ordinary trays , or ripple tank trays
- ii. Slinky
- iii. Eyedroppers

Pre-Activity assessment

Ask the learners how they perceive the sound of vehicles as they move towards them, pass close to them and speed away. Ask learners` opinion on how the traffic officers can be able to detect the speed of vehicles. Help learners to link this with the Doppler Effect.

Activity Assessment/evaluation

Learners will be given activity sheets which have clear instructions to carry out various tasks and activities. The activity sheets have questions and blank spaces where learners can write or draw depending on the question. The questions require learners to predict, observe and explain a phenomenon and in some cases draw diagrams to illustrate their answers (appendices 4, 5, and 6).

Post-Activity assessment

All the completed activity sheets to be marked and analysed

Activity extensions

- Learners to research on the subsonic speed, supersonic speed and sonic boom and determine its relationship to the Doppler Effect.
- Research on application of the Doppler Effect in a field of choice.
- How does a blind bat detect the flying insects and be able to fly without colliding with objects?

Table of Activities and objectives

Activity	Objectives of the activity	Activity sheet No.
<p>Slinky spring</p> <p>Teacher Activity</p> <ul style="list-style-type: none"> • Use a slinky spring, to demonstrate with the help of a learner how to construct a transverse wave. Ask a learner to draw the diagram of the wave on the board, ask other learners to identify and define: trough, crests, frequency and wavelength. 	<ul style="list-style-type: none"> i. to ensure that the learners can practically identify troughs and crests ii. the learners should be able to define the terms frequency and wavelength basing their definition on what they would have observed. iii. the learners should be able to observe 	1
<p>Learners` activity</p> <p>Divide the learners into groups of 5-</p>	<ul style="list-style-type: none"> i. The learners should be able to 	

<p>6. Each group gets a slinky. By experimenting the learners should find out how they can change the wavelength of the wave.</p>	<p>find the relationship between the frequency and wavelength.</p> <p>ii. The learner should be able to observe that the higher the frequency, the shorter the wavelength.</p>	<p>1</p>
<p>Water waves.</p> <p>Teacher activity:</p> <p>Divide class into groups of 5-6 and give each group a tray and an eyedropper. Ask the learners to fill the tray with water of about 1cm deep.</p> <p>Learners' activity:</p> <ol style="list-style-type: none"> 1. Use an eyedropper to drop water in the tray at regular intervals (eye dropper to remain stationary). 2. Draw your observations and write them down 3. Move the eyedropper in one direction along the tray while dropping the water. 4. Record and draw your observations. 	<p>i. The learner should predict what happens when the drop falls onto the water</p> <p>ii. The learner should be able to observe what happens.</p> <p>iii. the learner should be able to explain what is happening</p>	<p>2</p> <p>2</p>

<p>Teacher demonstration:</p> <ul style="list-style-type: none"> • Set up the ripple tank. • Produce waves by squeezing drops of water out of the dropper at regular intervals. (Explain that this is the frequency of the wave). • Continue to construct waves while moving the source towards the end of the tray marked by a lump of plasticine. • Repeat the demonstration until the learners have accurately observed the Doppler Effect with the teacher making the link. 	<ul style="list-style-type: none"> i. Repetition of learners' activity to check on their understanding of wavelength and frequency. ii. Learners should understand that the regular interval of drops represents the frequency of the wave. 	
<p>Extra activity: Passing vehicles</p> <ul style="list-style-type: none"> • Take learners by the road side and ask them to observe cars passing by and to describe what they hear. • If the school is far from the road, ask a learner to ride on a bicycle mounted with a cell phone (with external speaker) playing a high pitched tone at loud volume. The learner should start from afar and ride past the learners and continue 	<p>The learners should be able to predict that there will be a change in frequency of the sound as the source of sound approaches or moves away</p>	3

for a longer distance. Ask the learners to describe what they hear		
Doppler Effect calculations The learners will be given sheet of questions on the Doppler effect. The questions resemble those from the past examination papers.		4

Teachers` notes:

The teacher should help the learners to link the activities with the formula. The learners should be able to understand the following:

(a). The frequency affects the wavelength :

Faster frequency → shorter wavelengths

Slower frequency → longer wavelengths

(b) Movement affects wavelength:

Moving towards observer → shortens wavelength

Moving away from the observer → lengthen wavelength.

1. When the source of the wave is stationary, the distance between the waves are the same at both ends of the tray.
1. As the source of the wave moves, the distance between the waves will be shorter in the direction of the movement of the source and longer behind.
2. This is the Doppler Effect.

Appendix 5: Eyedropper

Activity sheet 2: Activities on the Doppler Effect

1. Keep the source of the wave (eyedropper) stationary and release drops at a constant rate. The constant falling of drops is the frequency. Draw the observed waves in the tank.
2. Based on what you have experienced with your slinky, **predict** what will happen to the waves in the tank when you move the dropper along the tray maintaining a constant frequency of drops.
3. Do the experiment and write your **observations** of the waves in the tank when the source (dropper) is moving along the tray and has a constant frequency of drops.
4. Summarize the relationship between wavelength and frequency and hence explain what you think is the Doppler Effect.

5. Give 3 examples of the Doppler Effect in everyday life.

4. Describe the Doppler Effect in terms of sound and make a comparison between water drops and the slinky spring.

Appendix 7: Grid code for computer SPSS data analysis

ID	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18
1	0	4	2	1	3	1	4	3	2	0	3	1	1	0	2	2	0	1
2	1	4	2	2	2	1	4	3	2	1	1	0	0	0	0	2	0	0
3	0	3	2	2	6	2	3	3	2	0	2	1	1	0	0	2	2	0
4	1	3	2	2	6	0	4	3	2	1	2	0	1	1	2	2	2	1
5	1	2	0	0	2	1	2	3	2	1	3	0	1	0	0	1	0	1
6	1	1	1	2	2	2	2	2	3	0	3	1	0	0	1	0	0	0
7	1	2	0	0	2	2	1	1	1	0	3	1	0	0	1	0	1	0
8	1	3	1	2	3	2	1	1	3	0	3	1	0	0	1	2	0	3
9	1	3	1	2	2	3	1	1	1	0	3	1	0	0	1	0	1	0
10	1	1	1	0	6	1	3	3	3	0	2	1	0	0	2	0	0	1
11	1	3	1	2	6	2	1	2	2	0	3	1	0	0	0	3	0	0
12	1	0	2	0	3	1	3	4	2	1	3	1	0	0	0	0	0	0
13	1	2	2	2	2	1	3	3	2	0	3	1	0	0	2	0	0	3
14	1	1	0	2	3	2	2	1	1	1	0	1	1	0	1	0	0	0
15	1	2	0	0	2	2	2	2	3	0	1	1	0	0	0	0	0	0
16	1	4	1	2	3	1	3	3	2	1	2	0	1	1	1	2	2	0
17	1	2	0	0	4	3	2	2	1	1	1	2	0	0	0	0	1	0
18	1	2	1	0	2	2	2	4	3	1	3	1	0	0	1	0	0	0
19	1	3	1	0	3	0	2	2	1	0	3	1	0	0	0	0	0	0
20	1	2	1	2	4	2	2	1	2	0	0	1	1	1	1	2	2	0

21	1	2	1	0	3	2	2	3	3	0	3	1	0	0	0	0	0	3
22	1	3	2	2	2	1	2	4	2	1	1	0	1	0	1	0	2	0
23	1	2	1	0	4	3	3	3	3	1	3	1	0	0	0	0	0	0
24	1	2	2	2	2	2	2	5	1	1	1	1	1	1	1	1	0	0
25	1	3	1	2	2	1	2	2	3	0	3	1	0	0	0	2	0	0
26	1	2	0	0	3	2	2	5	2	0	0	1	0	0	1	0	1	0
27	1	3	1	2	2	1	3	3	1	0	3	2	1	1	1	0	0	0
28	1	2	1	2	2	2	2	4	3	1	1	1	0	0	1	0	0	3
29	1	2	2	0	4	2	2	5	2	0	2	0	0	0	1	0	2	0
30	1	3	2	2	2	2	2	3	3	0	3	0	1	1	1	0	0	0
31	1	2	1	0	3	3	3	4	2	1	1	1	0	0	0	0	1	0
32	1	2	1	0	3	2	2	1	1	1	3	1	0	0	1	0	0	3

Appendix 8: Codes used in SPSS computer software for responses for the teachers` questionnaire

Personal Information

1. Gender

N=32

Gender	Total	%	code
Female	2	6.3	0
Male	30	93.7	1

2. Science teaching experience in years

	Total	%	code
0-5	1	3.1	0
6-10	3	9.4	1
11-15	15	46.9	2
16-20	10	31.3	3
Above 20	3	9.4	4

3. Teacher qualifications

	Total	%	code
Diploma	6	18.8	0
ACE	16	50.0	1
Degree	10	31.2	2

4. Type of school where the teacher is working.

Type of school	Total	%	code
Rural	14	43.8	0
Urban	1	3.1	1
Semi-urban/semi-rural	17	53.1	2

5. Total number of learners in grade 12 physical science classes

216

Content, support and teaching method(s)

6. How do you rate the level of difficulty of teaching the topic Doppler Effect?

	Total	%	code
Very easy	2	6.3	0

Easy	10	31.2	1
Difficult	16	50.0	2
Very difficult	4	12.5	3

7. How do you rate your understanding of the formula?

$$f_i = (v \pm v_i) / (v \pm v_s) \cdot f_s$$

	Total	%	code
Poor	0	0	0
fair	4	12.5	1
Satisfactory	17	53.1	2
Good	8	25.0	3
Very good	3	9.4	4

8. Do you discuss the application of Doppler Effect in everyday life with your learners?

	Total	%	code
Never	6	18.8	1
Just mention in passing	6	18.8	2
I Discuss	12	37.5	3

Tell them to access the internet	5	15.6	4
Tell them to read their textbooks	3	9.3	5

9. Under your given working conditions which do you think is important?

	Total	%	code
Rushing to finish the syllabus	8	25.0	1
Teaching at the rate at which learners understand	14	44.8	2
Drilling learners on past examination papers	10	31.2	3

10. Have you ever been trained while you were still at college or university on the topic Doppler Effect?

	Total	%	code
Yes	14	43.7	1
No	18	56.3	0

11. How have organised workshops on Doppler Effect enhanced your teaching skills on the topic?

	Total	%	code
Very little	3	9.4	0
Little	7	21.9	1
A lot	5	15.6	2
I have never attended a workshop on the Doppler effect	17	53.1	3

12. Have you ever done any experiment/demonstration for your learners on the Doppler Effect?

	Total	%	code
Sometimes	7	21.8	0
Never	23	71.9	1
Always	2	6.3	2

13. Do you have access to computers to teach the topic?

	Total	%	code
Yes	11	34.4	1
No	21	65.6	0

14. Are you using the computer to teach the topic?

	Total	%	code
Yes	6	18.7	1
No	26	81.3	0

15. How would you comment on the text books that you have?

	Total	%	code
Not enough	12	37.5	0
Enough but irrelevant	16	50.0	1
Enough and relevant	4	12.5	2

16. Briefly describe how you would teach the topic Doppler Effect?

Method/activity	Total	%	code
Explain, give notes, define terms	21	65.6	0
Explain, give notes, do practicals/ demonstrations	2	6.3	1
Explain, give notes, work out problems, discuss applications	8	25.0	2
No idea	1	3.1	3

17. How would you know the learners understood the Doppler Effect?

Method used to check	Total	%	code
Giving tests, class work, homework	21	65.6	0
Asking of questions during lesson	5	15.6	1
Application of knowledge, discussions, correctly solved problems	6	18.8	2

18. Comment on the availability of science apparatus and equipment at your school

Comment	Total	%	code
No equipment/apparatus	23	71.8	0
Few, not enough	4	12.5	1
Enough equipment/apparatus	0	0	2
Available but irrelevant to the topic	5	15.6	3

Appendix 9: Application letter for permission to conduct study

Azwifarwi Secondary School
P.O. Box 2512
Thohoyandou
0950
29 July 2010

The District Senior Manager
Department of Education
P. B. X2260. 0970
Limpopo Province

REF: ADMINISTRATION OF RESEARCH INSTRUMENTS TO LEARNERS, SUBJECT ADVISORS AND TEACHERS.

Dear Sir

I hereby apply for permission to conduct my research in the Thohoyandou cluster. The title of my research is: Challenges and prospects in teaching the Doppler Effect at Grade 12.

The answers to the questionnaires and interviews may bring out important information which will be used to establish the challenges faced by teachers in teaching this topic.

I am a student at UNISA and my student number is 4550 3923. My supervisor is Prf. J Kriek. I am also a Physical Science and mathematics teacher at Azwifarwi Secondary School, in the Thohoyandou cluster. I would like to inform you of the following:

- Only teachers in the Thohoyandou cluster are going to complete one questionnaire each.
- Learners will carry-out experiments and complete activity sheets on the Doppler Effect.
- The interviewing (for subject advisors). Administration of questionnaires (for teachers) and collection of questionnaires is going to be done by myself.
- Teachers are not going to be forced to complete the questionnaires and confidentiality is to be maintained.

Once permission is granted in the District I will also ask permission from the principals of the schools concerned.

The results of the findings will be made available to you and these might help in improving on the teachers` effectiveness and learner performance.

Yours Faithfully

Mr. Sure Mupezeni

My cell number: 084 3363 655

Appendix 10 A: Permission letter to conduct the study



LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

Ref: 14/7/R
Enq: M.S.Matibe
Contact: 0159621029

DEPARTMENT OF
EDUCATION
VHEMBE DISTRICT

Mr Sure Mupezeni
Arwifarwi Secondary School
P.O. BOX 2512
Thohoyandou
0950



APPLICATION FOR PERMISSION TO CONDUCT RESEARCH

1. The above matter bears reference.
2. Your application for permission to conduct research by administering instruments to subject advisors and teachers on challenges and prospects in teaching Droppler effect in grade 12 in Thohoyandou cluster has been approved.
3. You are expected to inform Circuit Managers and principals of effect schools prior to your visits.
4. Kindly ensure that your interactions with learners and teachers does not disrupt teaching and learning activities in schools.
5. Wishing you the best in your quest for intellectual achievement.


DISTRICT SENIOR MANAGER

17/08/2010
DATE

Thohoyandou Government Building, Old Parliament, Block D, Private Bag X2250, SIBASA, 0970
Tel: (015) 962 1313 or (015) 962 1331, Fax: (015) 962 6039 or (015) 962 2288

The heartland of southern Africa - development is about people!



21 July, 2011

Our Ref: 2011/ISTE/015b

Mr. Sure Mupezeni

South Africa

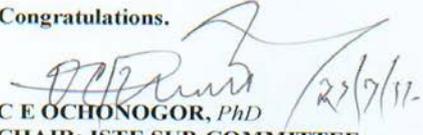
Dear Mr. Mupezeni,

REQUEST FOR ETHICAL CLEARANCE: "Challenges and Prospects of teaching Doppler Effect at Grade 12"

Your application for ethical clearance of the above study was considered by the ISTE sub-committee on behalf of the Unisa Research Ethics Review Committee on 21 July, 2011.

After careful consideration, your application is hereby **approved** and hence you can continue with the study at this stage.

Congratulations.


C E OCHONOGOR, PhD
CHAIR: ISTE SUB-COMMITTEE

cc. PROF T S MALULEKE
EXECUTIVE DIRECTOR: RESEARCH

PROF M N SLABBERT
CHAIR- UREC.



Appendix 11: Verbatim analysis of the interview with the subject advisor

1. Sir, for how long have you been a Science subject Advisor?
2. *Not very long under this current post, less than 3 years*
3. May you comment on the learners' performance in NSC final examinations in
4. Physical Science?
5. *The performance is not pleasing in most of the schools, but we have some*
6. *schools which are doing very well, but in general the performance is not what*
7. *we would want, the pass rate is still too low.*
8. According to your opinion what might be the causes of such performance by
9. the learners?
10. *There are many factors in play, but the main ones are that teachers lack*
11. *content knowledge and that some teachers are under qualified to teach the*
12. *subject. The other thing is that our learners are not motivated; they need to*
13. *be constantly motivated.*
14. Please comment on teacher qualifications and experience in the subject in
15. your district?
16. *As I have said some teachers are under qualified so their content knowledge*
17. *is questionable, but we try to help them with supplementary teaching*
18. *materials and study guides. We are ensuring that every grade 12 teacher is*
19. *qualified to teach the subject he/she will be teaching and I am sure almost all*
20. *schools will be having competent teachers soon in mathematics and physical*
21. *science.*
22. What are the teachers' main concerns regarding the topic Doppler Effect?
23. *The problem is on the calculations, use of the formula, how the formula*
24. *changes under a given situation, also linking the theory with the practical real*
25. *life situations for the learners to understand.*
26. What do you consider as main challenges regarding the topic Doppler Effect?
27. *Understanding of the topic, teachers lack content knowledge on the topic and*
29. *this will make it difficult for them to explain to the learners remember this is a*
30. *new topic to most teachers.*
31. Which method(s) are the teachers using when teaching this topic?

32. Really teachers use different methods, but we encourage them to use learner
33. centred methods, not just talking and talking, learners need to participate,
34. they must take part in the learning process, science is a practical subject. We
35. would like teachers to carryout experiments to show learners the practical
36. side of the theories. We are aware that not all schools have science
37. laboratories and those with the laboratories might not have all the necessary
38. equipment. Efforts are being made to equip the schools.

39. Which method would you suggest to be most effective when teaching this
40. topic Doppler Effect?

41. Where possible demonstrations and practicals would be better, because
42. learners will understand and remember more what they see and do.

43. What guidance or support is available to teachers to help them with this
44. topic?

45. We supply schools with study guides, we sometimes do workshops, there are
46. so many things for us to do, so at times the planned workshops are not done
47. due to different reasons, we are aware of the teachers problems. Doppler
48. Effect is a difficult topic workshops must be organised to assist teachers.

49. Any observations regarding the teaching of Doppler Effect that you have
50. made over the years, which you might want to share?

51. Just like any topic the learners need to understand the link with their everyday
52. life, why we learn the topic in the first place, and at times teachers just teach
53. the theory with no experiments or demonstrations.

Appendix 12: Test on Doppler Effect Calculations

Lesson 2: Calculations on the Doppler Effect

Duration of Lesson: 1 class period (30 minutes)

Lesson objectives

- 1) Learners should be able to read and understand the questions.
- 2) Learners should be able to diagrammatize the situation being portrayed in the question.
- 3) Learners should be able to solve problems using the Doppler effect equation.

Pre-activity assessment

Discuss with learners their everyday experiences with the Doppler Effect. Let the learners explain how Doppler Effect can help the blind people.

Activity assessment/ Evaluation

The learners will be issued with question papers. They will answer the questions on the spaces provided on the question paper. The teacher will collect the completed answers and mark them.

Post- activity assessment

All answer sheets will be marked and analysed.

Activity extensions

Learners to be given an assignment set from final grade 12 past examination papers.

Activity sheet 4:

Marks: 18

Question 1

A blind lady is standing at a bus stop, a police car moving at $45\text{m}\cdot\text{s}^{-1}$, sounding its siren approaches the bus stop. The siren of the police car emits sound waves at a frequency of 360 Hz. As the car approaches the lady, the pitch of sound that she hears gets higher and decreases as the car passes her and moves off.

Show why the pitch of the sound that the blind lady hears is

1 Higher as the car approaches her, use a sketch of wave fronts. (2)

2 Lower as the car moves away from her (2)

1.3 Determine the apparent frequency of the sound waves that the lady hears while the police car approaches her. Take speed of sound in air as $344\text{ m}\cdot\text{s}^{-1}$ (5)

1.4 Name this phenomenon and explain how it can help the blind lady. (2)

Question 2

An ambulance with its siren on is moving at $25\text{m}\cdot\text{s}^{-1}$ towards the hospital. A traffic officer standing next to the road with a detector, measures the frequency of the sound emitted by the siren to be 370 Hz. The measured frequency is LOWER than the frequency of the sound emitted by the siren.

2.1 State whether the ambulance is moving toward or away from the traffic policeman? (1)

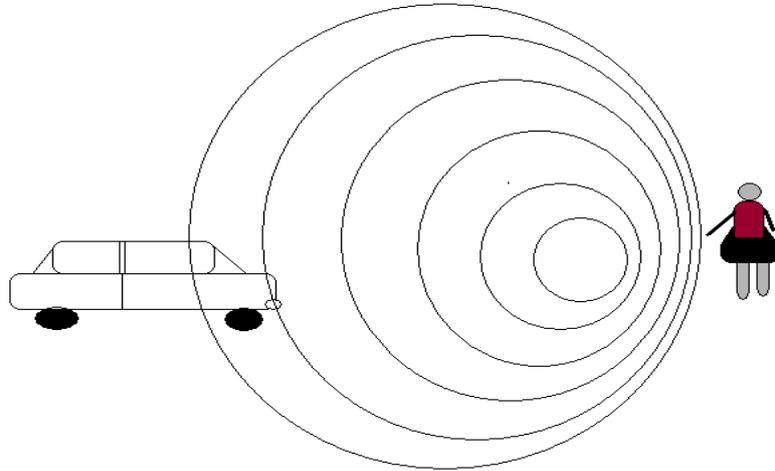
2.2 Explain why the registered frequency is lower. (1)

2.3 If the speed of sound in air is 320ms^{-1} , calculate the frequency of the siren. (4)

Suggested answers to questions 1 and 2

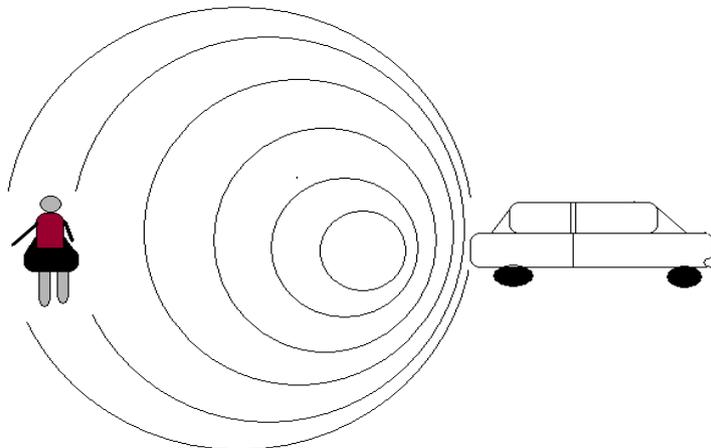
Question 1

1.1



The car approaches the lady

1.2



The car moves away from the lady

1.3

$$f_i = \frac{v \pm v_l}{v \pm v_s} f_s$$

$$= \left(\frac{344}{344 - 45} \right) \times 360$$

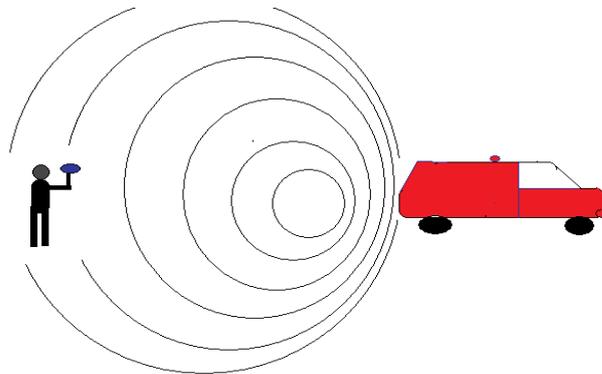
$$= 414 \text{ Hz}$$

1.4 The Doppler Effect. The lady can be able to tell whether a car is near or far away, if she hears a low pitch of sound this tells her that the car is far and she can cross the road safely.

Question 2

2.1 Moving away from the traffic officer

2.2 The low frequency indicates that the ambulance is going away; where the waves are compressed it shows point of high frequency and shorter wavelength.



2.3

$$f_i = \frac{v \pm v_1}{v \pm v_2} f_s$$

$$370 = \left(\frac{320}{320 + 25} \right) \times f_s$$

$$f_s = 397.85 \text{ Hz}$$

Appendix 13: Correlation

Table 20: Pearson's product moment Correlation

Mark range	D	Q	D ²	Q ²	DQ
90-100	0.9	1.9	0.8	3.6	1.71
80-89	8.3	3.2	68.9	10.2	26.56
70-79	15.7	4.6	246.5	21.2	72.22
60-69	24.5	6.4	600.3	41.0	156.8
50-59	26.4	16.1	697.0	259.2	425.04
40-49	15.3	19.9	234.1	396.0	304.47
30-39	5.1	26.4	26.0	697.0	134.64
20-29	3.7	15.2	13.7	231.0	56.24
10-19	0	6.0	0	36.0	0
0-9	0	0	0	0	0
216	99.9	99.7	1887.3	1695.2	1177.68
(N)	(ΣD)	(ΣQ)	(ΣD^2)	(ΣQ^2)	(ΣDQ)

Using the above figures and the formula the value of r has been calculated; $r = 0.649394384$ which is approximately $r = 0.65$ and this indicates a high correlation according to description below (Mulder, 1993:73).

1.00 - perfect correlation

0.80 to 0.99 - very high correlation

0, 60 to 0.79 - high correlation

0.40 to 0.59 - moderate correlation

0.20 to 0.39 - low correlation

0.01 to 0.19 - very low correlation

0.00 - no correlation

Appendix 14: Interview questions for teachers and learners after the Lesson

After the lesson some teachers were asked this question:

- ✓ What is your opinion on the lesson?

A few learners were randomly picked and asked this question:

- ✓ How was the lesson?

Appendix 15: SPSS statistical analysis of teachers' questionnaire

gender * type of school Crosstabulation

Count

		type.of.school			Total
		rural	urban	semi-urban	
gender	female	0	1	1	2
	male	14	0	16	30
Total		14	1	17	32

Table 15

qualification * type.of.school Crosstabulation

Count

		type.of.school			Total
		rural	urban	semi-urban	
qualification	diploma	5	0	1	6
	ACE	7	0	9	16
	degree	2	1	7	10
Total		14	1	17	32

Table 16

level.of.difficulty * understanding.formular Crosstabulation

Count

	understanding.formular	Total

		fair	satisfactory	good	very good	
level.of.difficulty	very easy	0	1	0	1	2
	easy	0	3	5	2	10
	difficult	3	12	1	0	16
	very difficult	1	1	2	0	4
Total		4	17	8	3	32

Table 17

Correlations

		availability.equipm ent	exp.demonstratio ns
availability.equipment	Pearson Correlation	1	.055
	Sig. (2-tailed)		.765
	N	32	32
exp.demonstrations	Pearson Correlation	.055	1
	Sig. (2-tailed)	.765	
	N	32	32

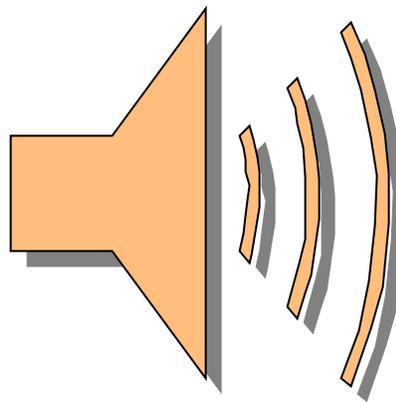
Table 18

Correlations

			availability.equipm ent	exp.demonstratio ns
Spearman's rho	availability.equipment	Correlation Coefficient	1.000	-.027
		Sig. (2-tailed)	.	.885
		N	32	32
	exp.demonstrations	Correlation Coefficient	-.027	1.000
		Sig. (2-tailed)	.885	.
		N	32	32

Table 19

INSTRUCTIONAL MANUAL



PHYSICS: THE DOPPLER EFFECT

SURE MUPEZENI

JEANNE KRIEK

Foreword

In view of the critical role that science, mathematics and technology play in the social, economic and industrial development this instruction manual attempts to encourage learners to learn practically, to link science phenomenon with their every day experiences. This manual covers only the topic Doppler Effect. It provides a guide to enhance the capacity of teachers to improve on the understanding by learners of the Doppler Effect.

We hope you will enjoy using this manual and that it will help improve the learner performance in Physical Science and build a stronger foundation for the development of South Africa.

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The Doppler Effect

The Doppler Effect is the apparent change of frequency and wavelength of a wave when the source or the observer moves relative to each other (Gibbs, 1997). When dealing with sound, if a source of the wave (car sounding a siren) and an observer are moving relative to each other, the observed frequency is different from the source frequency. When the source and observer are moving away from each other, the observed frequency is less than the source frequency. This is due to the sound waves being stretched to create lower frequency sound waves. When the source and observer are moving towards each other, the observed frequency is greater than the source frequency. In reality the sound waves are being compressed, causing a higher frequency to be heard by the listener/observer. This phenomenon is called the Doppler Effect.

A familiar example is the change in pitch of an ambulance siren when the ambulance is approaching or receding. When the ambulance approaches the observer, the observer receives a higher frequency as compared to the emitted frequency and the frequency is the same at the instant of passing, and gets lower as the ambulance speeds away. The explanation of the relative increase in frequency is as follows:

When the source of the waves is moving toward the observer, each successive wave crest is emitted from a position closer to the observer than the previous wave. Therefore, each wave takes slightly less time to reach the observer than the previous wave. Therefore, the time between the arrivals of successive wave crests at the observer is reduced, causing an increase in the frequency. While they are travelling, the distance between successive wavefronts is reduced; so the waves “bunch together”. Conversely, if the source of waves is moving away from the observer, each wave is emitted from a position farther from the observer than the previous wave, so the arrival time between successive waves is increased, reducing the frequency. The distance between successive wavefronts is increased, so the waves “spread out”.

This relationship can be summarized mathematically by an equation below;

$$f_l = \left(\frac{v \pm v_l}{v \mp v_s} \right) f_s$$

Where

v = speed of sound in the medium

v_s = the velocity of source of sound

v_l = the velocity of observer

f_s = the frequency emitted by source of sound

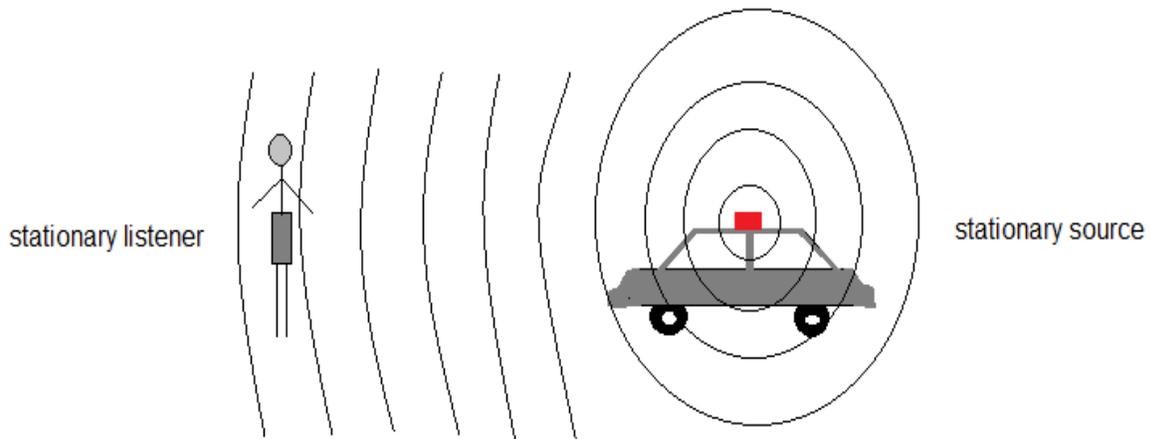
f_l = the frequency heard by the observer/listener

Note that the above formula can only be used for sound waves provided the speeds of the receiver and source relative to the medium are lower than the speed of sound. Doppler Effect is applied differently for sound and light waves due to the following two reasons:

- a) Sound waves are mechanical and require a medium to travel, whereas light waves are electromagnetic and do not require any medium for their propagation.
- b) The velocity of light is the same in all inertial frames of reference, but the velocity of sound is not.

Scenarios illustrating the Doppler Effect:

1. Stationary source , stationary listener



$$f_l = f_s$$

The frequency heard by observer is equal to the frequency emitted by the source if they are close together.

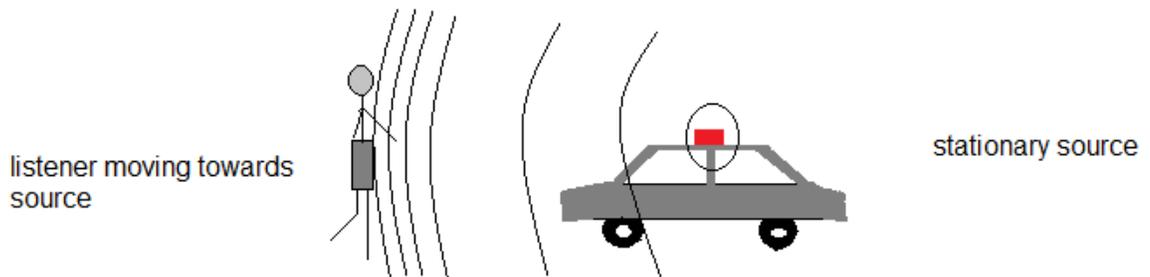
2. Moving listener, stationary source

$$f_l = \frac{v \pm v_l}{v} f_s$$

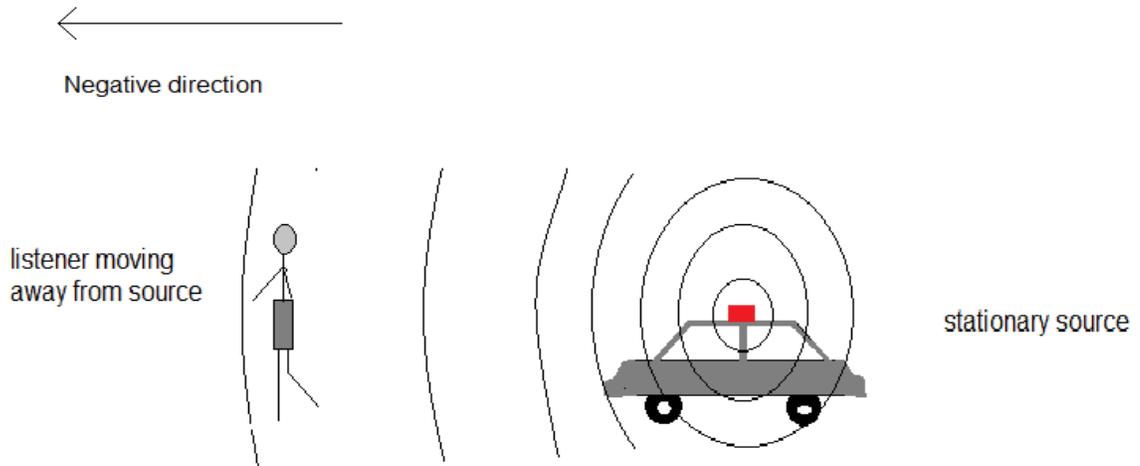
- the plus sign applies when listener moves towards the source as shown below:



Positive direction



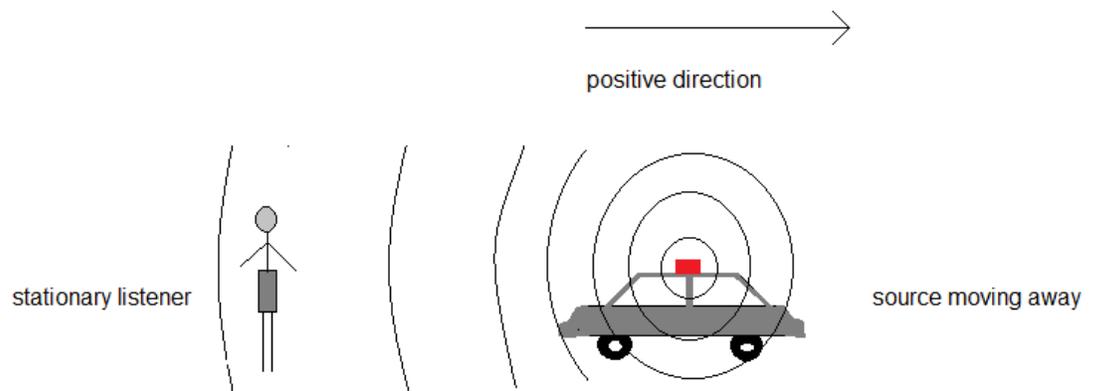
- The negative sign applies when the listener moves away from the source of sound.



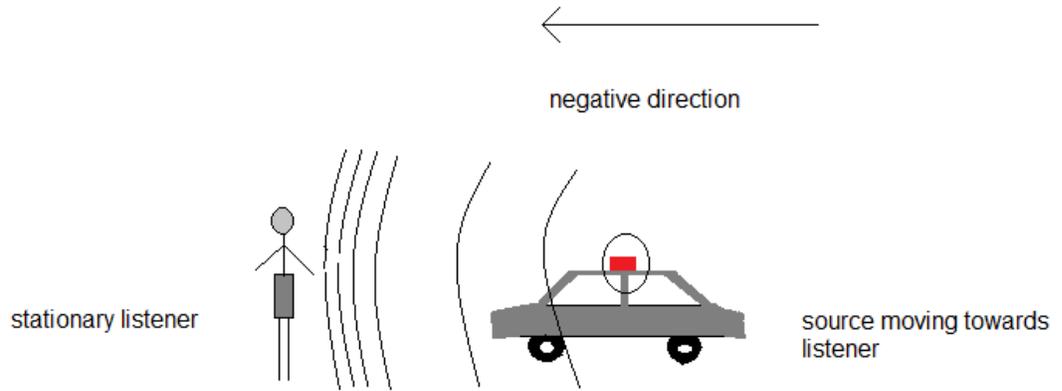
3. Stationary listener, moving source

$$f_l = \frac{v}{v \pm v_s} f_s$$

- the plus sign applies when source moves away from the listener



- the negative sign when source of sound moves towards the listener



4. Moving listener, moving source

$$f_i = \frac{v \pm v_l}{v \pm v_s} f_s$$

- the upper sign positive and lower sign negative apply to source/ listener moving towards each other.
- The upper sign negative and lower sign positive apply to listener/source moving away from each other (Lowe & Rounce, 1997).

Why the Doppler Effect is sometimes included under light and sometimes with sound?

There are two reasons for the difference in the application of the Doppler Effect for sound and light waves. Firstly, the sound waves are mechanical and they require a medium to travel through. Secondly, the velocity of light waves is the same in all inertial frames of references but the velocity of sound is not. The formula;

$$f_i = \frac{v \pm v_l}{v \pm v_s} f_s$$

applies to sound waves, if and only if the speeds of the source of sound and the observer relative to the medium are slower than the speed of sound (Lowe & Rounce, 1997).

However, the Doppler Effect is also included under the topic light where the speed of the wave is far greater than the relative speeds of source and observer, the example is that of electromagnetic waves, the Doppler Shift. The Doppler Effect for electromagnetic waves like light is used in astronomy to show a red shift or a blue shift. The spectra of stars are not continuous; instead they exhibit absorption lines that are not always at the frequencies that are obtained from the spectrum of a stationary light source. Red light has a lower frequency than blue light, the spectral lines of an approaching astronomical light source exhibit a blue shift and those of receding light source exhibit a red shift. This has helped scientists to realize that galaxies were moving away, they concluded that the universe is expanding.

Applications

1. Astronomy. The Doppler Effect for light has helped scientists in realizing that the earth is expanding. It was discovered that the distant a galaxy is, the faster it is moving away from the earth (Thinkquest, 2009). The Doppler Effect for light results in either a redshift or a blue shift. The use of Doppler Effect in space research depends on the fact that spectra of stars are not continuous therefore they exhibit absorption lines at well defined frequencies. It is known that blue light has a higher frequency than red light, the spectral lines of a receding astronomical light source exhibit a redshift and an approaching light source exhibit a blue shift.
2. Medicine: An echocardiogram produces an assessment of the direction of blood flow and the velocity of blood and cardiac tissue at any point on a human body using Doppler Effect. The measurement of blood flow rate in veins and arteries based on Doppler Effect is used for diagnosis of vascular problems like stenosis (Evans & McDicken, 2000).

3. Radar: Doppler Effect is used to measure the velocity of detected objects like cars (by traffic policemen) or airplanes.
4. Underwater acoustics: The speed of a submarine can be calculated by the Doppler shift in military applications.

A worked example:

If you are standing at the bus stop you can tell whether a distant bus is approaching or moving away by listening to the pitch (frequency) of the sound produced by the bus engine.

- a) The phenomenon above describes which property of waves?
- b) A man at a football game observes a boy blowing a *vuvuzela* and running towards him at a speed of 0.95ms^{-1} . The vuvuzela produces a note of frequency 790Hz . If the speed of sound is 340ms^{-1} on that day, calculate the frequency heard by the man.

Answers:

- a) The Doppler Effect
- b) The source of sound (vuvuzela) is moving towards the man.

$$f_l = \left(\frac{v}{v-v_s}\right)f_s = 340/(340-0.95) \times 790 = 792,2\text{Hz}$$

Lesson 1: The Doppler Effect

Duration of lesson: 2 class periods

Lesson objectives

- i. Learners should be able to list the factors which affect the wavelength of a wave.
- ii. Learners should be able to explain the relationship between wavelength and frequency.
- iii. Learners should be able to explain what the Doppler Effect is.

Materials needed

- i. ripple tank trays
- ii. Slinky springs
- iii. Eyedroppers

Pre-Activity assessment

Discuss with the learners their life experiences of the Doppler Effect. Ask the learners how they perceive the sound of vehicles as they move towards them, pass close to them and speed away.

Activity Assessment/evaluation

Learners use activity sheets. Learners fill out the Doppler Effect activity sheets copied from this manual.

Post-Activity assessment

All the completed activity sheets to be marked and analyzed

Activity extensions

- Learners to research supersonic speed, Mach number, sonic boom and determine its relationship to the Doppler Effect.
- Research on application of the Doppler Effect in a field of choice.

Table of Activities and objectives

Activity	Objectives of the activity	Activity sheet No.
<p>Slinky spring</p> <p>Teacher Activity</p> <ul style="list-style-type: none"> Use a slinky spring, to demonstrate with the help of a learner how to construct a transverse wave. Ask a learner to draw the diagram of the wave on the board, ask other learners to identify and define: trough, crests, frequency and wavelength. 	<ol style="list-style-type: none"> to ensure that the learners can practically identify troughs and crests the learners should be able to define the terms frequency and wavelength basing their definition on what they would have observed. the learners should be able to observe during the experiments. 	1
<p>Learners` activity</p> <p>Divide the learners into groups of 5-6. Each group gets a slinky. By experimenting the learners should find out how they can change the wavelength of the wave.</p>	<ol style="list-style-type: none"> The learners should be able to find the relationship between the frequency and wavelength. The learner should be able to observe that the higher the frequency, the 	1

	shorter the wavelength.	
<p>Water waves.</p> <p>Teacher activity:</p> <p>Divide class into groups of 5-6 and give each group a tray and an eyedropper. Ask the learners to fill the tray with water of about 1cm deep.</p> <p>Learners' activity:</p> <ol style="list-style-type: none"> 1. Use an eyedropper to drop water in the tray at regular intervals (eye dropper to remain stationary). 2. Draw your observations and write them down. 3. Move the eyedropper in one direction along the tray while dropping the water. 4. Record and draw your observations. 	<ol style="list-style-type: none"> i. The learner should predict what happens when the drop falls onto the water. ii. The learner should be able to observe what happens. iii. the learner should be able to explain what is happening 	<p>2</p> <p>2</p>
<p>Teacher demonstration:</p> <ul style="list-style-type: none"> • Set up the ripple tank. • Produce waves by squeezing drops of water out of the 	<ol style="list-style-type: none"> i. Repetition of learners' activity to check on their understanding of wavelength and frequency. ii. Learners should 	

<p>dropper at regular intervals. (Explain that this is the frequency of the wave).</p> <ul style="list-style-type: none"> • Continue to construct waves while moving the source towards the end of the tray marked by a lump of plasticine. • Repeat the demonstration until the learners have accurately observed the Doppler Effect with the teacher making the link. 	<p>understand that the regular interval of drops represents the frequency of the wave.</p>	
<p>Extra activity: Passing vehicles</p> <ul style="list-style-type: none"> • Take learners by the road side and ask them to observe cars passing by and to describe what they hear. • If the school is far from the road, ask a learner to ride on a bicycle mounted with a cell phone (with external 	<p>The learners should be able to predict that there will be a change in frequency of the sound as the source of sound approaches or moves away.</p>	<p>3</p>

<p>speaker) playing a high pitched tone at loud volume. The learner should start from afar and ride past the learners and continue for a longer distance. Ask the learners to describe what they hear.</p>		
<p>Doppler Effect calculations</p> <p>The learners will be given sheet of questions on the Doppler effect. The questions resemble those from the past examination papers.</p>		<p>4</p>

Teachers` notes:

The teacher should help the learners to link the activities with the formula. The learners should be able to understand the following:

(a). The frequency affects the wavelength :

Faster frequency → shorter wavelengths

Slower frequency → longer wavelengths

(b) Movement affects wavelength:

Moving towards observer → shortens wavelength

Moving away from the observer → lengthen wavelength.

1. When the source of the wave is stationary, the distance between the waves are the same at both ends of the tray.

3. Define frequency. How did you change the frequency of the wave?

Activity 2: Eyedropper

1. Keep the source of the wave (eyedropper) stationary and releasing constant frequency of drops. Draw and list five observations of the waves in the tank.

2. Based on what you have experienced with your slinky spring, **predict** what will happen to the waves when you move the dropper along the tray maintaining a constant frequency of drops.

3. Draw and list 5 **observations** of the waves in the tank when the source (dropper) is moving and has a constant frequency of drops.

4. Summarize what the Doppler Effect is.

5. Give 3 example of the Doppler Effect in everyday life.

4. Describe the Doppler Effect in terms of sound and make a comparison between water drops and the slinky spring.

Lesson 2: Calculations on the Doppler Effect

Duration of Lesson: 2 class periods

Lesson objectives

- 1) Learners should be able to read and understand the questions.
- 2) Learners should be able to draw diagrams representing the situation being portrayed in the question.
- 3) Learners should be able to solve problems using the Doppler Effect equation.

Materials needed

Question papers, answer sheets, calculators

Pre-activity assessment

Discuss with learners their everyday experiences with the Doppler Effect. Let the learners explain how Doppler Effect can help the blind people.

Activity assessment/ Evaluation

The learners will answer questions from activity sheet.

Post- activity assessment

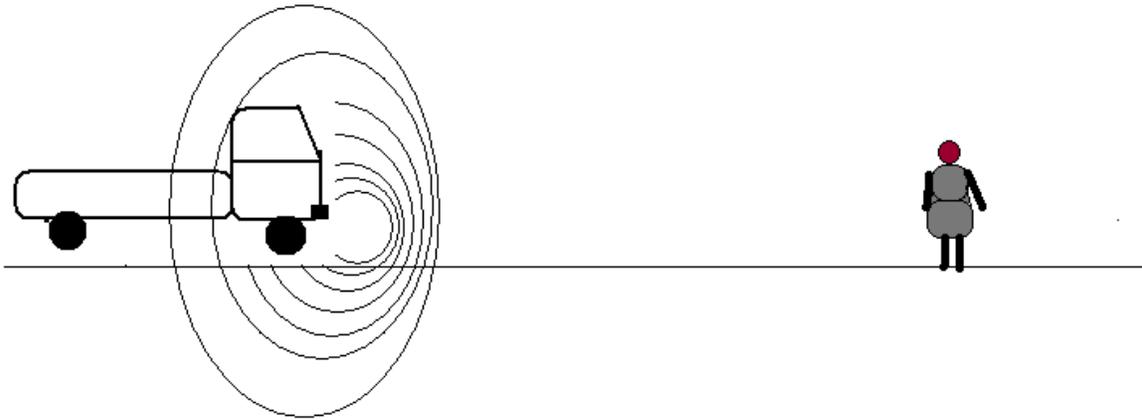
All answer sheets will be marked and analyzed.

Activity extensions

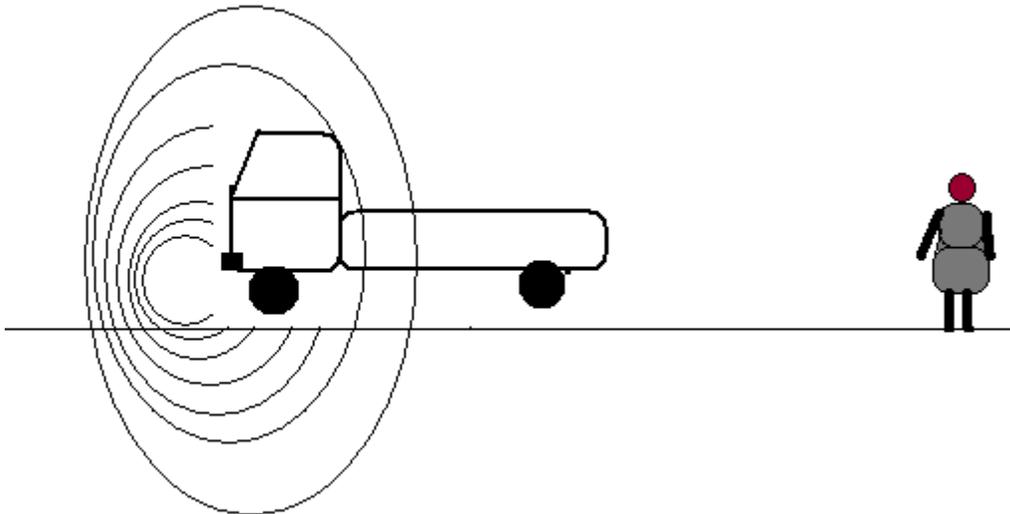
Learners to be given an assignment in the form of questions; which are similar to those of the physical science final examinations.

Introduction to calculations on the Doppler Effect

Carefully observe the two diagrams below and indicate in which diagram would the observer hear a lower frequency?



Approaching truck with compressed sound waves



Receding truck with stretched sound waves.

Activity 4: Doppler Effect Calculations

Question 1

A blind lady is standing at a bus stop, a police car moving at $45\text{m}\cdot\text{s}^{-1}$, sounding its siren approaches the bus stop. The siren of the police car emits sound waves at a frequency of 360 Hz. As the car approaches the lady, the pitch of sound that she hears gets higher and decreases as the car passes her and moves off.

Show why the pitch of the sound that the blind lady hears is

1.1 Higher as the car approaches her, use a sketch of wave fronts. (2)

1.2 Lower as the car moves away from her (2)

1.3 Determine the apparent frequency of the sound waves that the lady hears while the police car approaches her. Take speed of sound in air as $344\text{ m}\cdot\text{s}^{-1}$ (5)

1.4 Name this phenomenon and explain how it can help the blind lady. (2)

Question 2

An ambulance with its siren on is moving at $25\text{m}\cdot\text{s}^{-1}$ towards the hospital. A traffic officer standing next to the road with a detector, measures the frequency of the sound emitted by the siren to be 370 Hz. The measured frequency is LOWER than the frequency of the sound emitted by the siren.

2.1 State whether the ambulance is moving toward or away from the traffic policeman?(1)

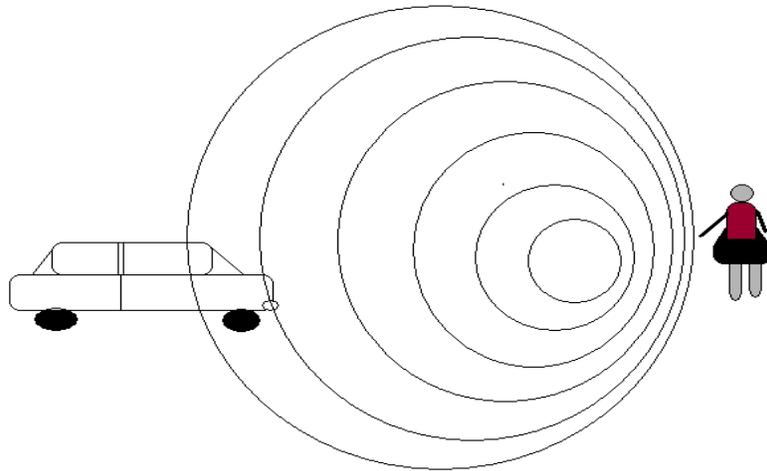
2.2 Explain why the registered frequency is lower. (2)

2.3 If the speed of sound in air is 320 m.s^{-1} , calculate the frequency of the siren. (4)

Suggested answers to questions 1 and 2

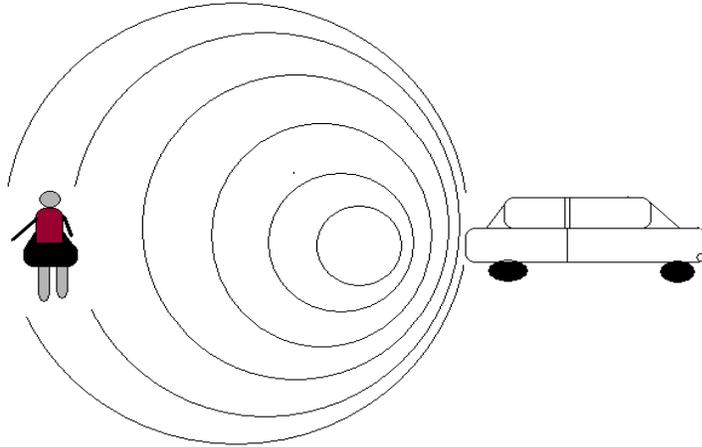
Question 1

1.1



The car approaches the lady

1.2



The car moves away from the lady

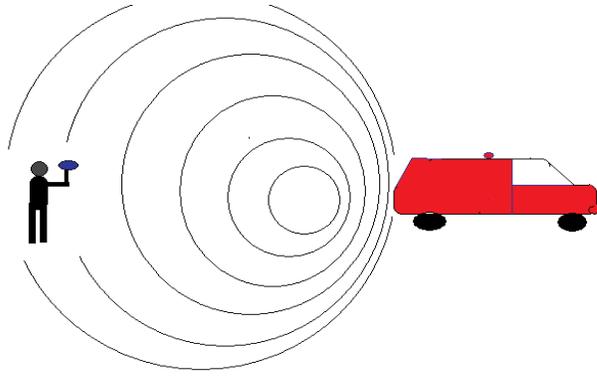
$$\begin{aligned}
 1.3 \quad f_o &= \left(\frac{v \pm v}{v \mp v} \right) f \\
 &= \left(\frac{344}{344 - 45} \right) \times 360 \\
 &= 414 \text{ Hz}
 \end{aligned}$$

1.4 The Doppler Effect. The lady can be able to tell whether a car is near or far away, if she hears a low pitch of sound this tells her that the car is far and she can cross the road safely.

Question 2

2.1 Moving away from the traffic officer

2.2 The low frequency indicate that the ambulance is going away, where the waves are compressed it shows point of high frequency and shorter wavelength



$$2.3 \quad f_o = \left(\frac{v \pm v}{v \mp v} \right) f_s$$

$$370 = \left(\frac{320}{320 + 25} \right) \times f_s$$

$$f_s = 398.91 \text{ Hz}$$

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